WATER SECURITY: FUTURE PROSPECTS FOR INDIA

A Dissertation submitted to the Punjab University, Chandigarh for the award of Master of Philosophy in Social Sciences, in Partial Fulfilment of the requirement for the Advanced Professional Programme in Public Administration (APPPA)

By

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INDIAN INSTITUTE OF PUBLIC ADMINISTRATION

NEW DELHI

CERTIFICATE

I have the pleasure to certify that **Air Commodore KSK Suresh, VM** has pursued his research work and prepared the present dissertation titled "**Water Security: Future Prospects for India**" under my guidance and supervision. The dissertation is the result of his own research and to the best of my knowledge, no part of it has earlier comprised any other monograph, dissertation or book.

This is being submitted to the Punjab University, Chandigarh, for the purpose of **Master of Philosophy in Social Sciences** in partial fulfilment of the requirement for the Advanced Professional Programme in Public Administration (APPPA) of the Indian Institute of Public Administration (IIPA), New Delhi.

I find that the dissertation of **Air Commodore KSK Suresh, VM** is worthy of consideration and recommend it for the award of M.Phil degree of Punjab University, Chandigarh.

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DECLARATION

I, the undersigned, hereby declare that this dissertation entitled, "**Water Security: Future Prospects for India**", is my own work, and that all the sources I have accessed or quoted have been indicated or acknowledged by means of completed references. The dissertation has not been submitted for any other degree of this university or elsewhere.

Date: March 2019
Place: New Delhi

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ABBREVIATIONS

S No	Acronym	Expanded Form
1.	APFMGS	Andhra Pradesh Farmer Managed Groundwater Systems
2.	API	Application Programming Interface
3.	BAU	Business as Usual
4.	BCM	Billion Cubic Meters
5.	CGWB	Central Ground Water Board
6.	CWMI	Composite Water Management Index
7.	DBT	Direct Benefit Transfer
8.	DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
9.	FAO	Food and Agriculture Organisation
10.	GIS	Geographic Information System
11.	ILR	Inter Linking of Rivers
12.	IPC	Irrigation Potential Created
13.	IPCC	Inter governmental Panel on Climate Change
14.	IPU	Irrigation Potential Utilized
15.	IWRM	Integrated Water Resource Management
16.	IWMP	Integrated Watershed Management Programme
17.	LPG	Liquified Petroleum Gas
18.	MDWS	Ministry of Drinking Water and Sanitation
19.	MIS	Management Information System
20.	MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
21.	MOWR	Ministry of Water Resources
22.	NGO	Non-governmental Organisation
23.	NITI	National Institution for Transforming India
24.	NPP	National Perspective Plan
25.	PIM	Participatory Irrigation Management
26.	PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
27.	PRI	Panchayati Raj Institutions
28.	RMDD	Rural Management and Development Department
29.	SCADA	Supervisory Control and Data Acquisition
30.	TERI	The Energy and Resources Institute

EXECUTIVE SUMMARY

Water today has become a precious and scarce commodity amongst global community. Though 3/4th of the earth's surface is covered with water the quantity that is available for human consumption is meagre and reducing rapidly. The crisis is looming large over India with millions of lives and livelihoods under threat. It is getting worse and with in another decade the country is likely to face water insecurity. As per the report of National commission for integrated water resource development of MoWR, the water availability by 2050 is likely to be 40 percent less than the demand. Hence, there is an urgent need to spread awareness amongst the populace to deepen our understanding of water resources and its management to put in place robust methodologies that make our water use efficient and sustainable. The two important studies that address the emerging water management issues are the Composite Water Management Index (CWMI) developed by National Institute for Transforming India (NITI) and the study on assessment of water footprints of India's long term energy scenarios conducted by The Energy and Resource Institute (TERI), India.

This research is carried out to comprehend the state of India's water resources management with respect to the following questions: 1) What are the existing water resources in India 2) What are the flaws in the existing water resource management, storage and development methods and 3) What are the suggested water preservation methodologies to ensure water security in the future.

A rough estimate of the water resource available in the country is discussed in chapter 2. The analysis based on the water foot print assessment gives a rosy picture, however, the complexities involved in harnessing various water resources requires to be addressed to avoid water misuse. Chapter 3 of this paper reviews the water source management practices prevalent in the country in an effort to know the methodology needed to solve tomorrow's water problems. In recent years there is adequate evidence to indicate that water security is becoming increasingly affected by climate change resulting in erratic weather patterns.

Another concern in the region is the growing competition amongst states and neighbouring countries over shared water resources. The water resource management in diverse landscape of India with wide range of physical features varying from cold mountains to arid desert, vast plains, hot and humid plateau and wide seasons and tropical islands is highly challenging task. The limiting factor is the availability of utilizable water resources against increased demand from all energy sectors.

India has huge potential for developing ground water resources. In chapter 4, ground water management challenges are discussed while carrying out case studies of some of the innovative initiatives launched within the country and reforms achieved in Israel and USA to achieve water sustainability. Their experiences hold important lessons to be learned from implementation across the country to mitigate water scarcity.

Various programmes implemented throughout the nation in different states have not responded in an adequate manner and there is no structure in place at the national level to evaluate and coordinate to provide long lasting solution. In chapter 5, the issue regarding awareness, responsibilities and governance in the management of a common finite water resource is analysed. Technology plays a vital role in influencing sound decisions regarding water resources planning and management. India's expertise in space technology can be exploited to confront emerging water problems.

The present water resource management methodology has many components comprising environmental, economic and social origin. Water Governance is one of main issue that requires to be addressed to find a solution for water sustainability in the future. The overuses of water, pollution, uneven availability of water in different regions of the country, inadequate recycling, and water mismanagement are some of the current problems. To cope with these problems and enhance strategies for long term management, certain approaches are suggested in the concluding chapter. They are a) Watershed development - integrating research, monitoring, data base and management b) Urban Water Pricing to improve socio-economic sustainability c) An efficient and improved On farm water management to increase agriculture productivity while optimizing water use d) A modern method to rejuvenate ground water and its restoration e) An improved water governance system based on participation of stakeholders and the public and private sector through better water regulation and participatory irrigation f) Innovative water harvesting methodologies g) Implementation of successful surface water restoration methods adopted by various states across the country h) Prioritizing and improving national water policy and j) Ensuring availability and improving the quality of rural drinking water.

The worsening water crisis in certain parts of the globe has highlighted the risks and challenges that lie ahead for India. If all stakeholders come together to address the issues of water management, success would be inevitable. The water resource management implementation should be through a bottom-up and decentralised approach. The measures adopted by the government on water security policy decisions and initiating and implementing various water rejuvenation schemes are steps in the right direction. The measures recommended in the research paper may be adapted to find a lasting solution and ensure water security in the future for India.

CHAPTER 1

INTRODUCTION

"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability".

- The UN definition of water security

Water is such a precious gift of nature to the humanity that no life can survive without water. But as a global community, we use too much of water and we use it unwisely. Though water covers 70.9 percent of the earth's surface, only 3 percent is fresh or potable, of which 2 percent is held in ice-caps and glaciers. Of the 1 percent, 30 percent is ground water and a mere 0.3 percent is found in lakes, ponds, rivers, streams, swamps, marshes and bogs, is non-frozen, salt-free, and accessible for human consumption. The limited fresh water available is depleting very fast and it can become a huge problem for the future generations. There is growing evidence of water insecurity in many parts of the world. However, the current conventional supply-side economics and management are insufficient to deal with the situation.

The general scarcity of water is often exacerbated by the more frequent occurrence of extreme weather phenomenon. But the global demand for water is increasing and the destruction of water-dependent ecosystems has accelerated. Rapid population growth in developing countries is contributing to critical environmental degradation and this degradation, along with inadequate water supply and sanitation services are imposing large health problems and burdensome economic costs on the poor. It is projected that two out of every three people on the planet will live in waterstressed conditions by the year 2030. In the last century, world population tripled and the use of water grew six times. By 2030, the demand for water is 40 percent more than it is currently consumed and 50 percent higher in the most rapidly developing countries. The planning commission, GoI has warned that India will face water crisis by the year 2025[1].

India is a land of many rivers and mountains. Its geographical area is criss-crossed by a large number of small and big rivers, some of them figuring amongst the mighty rivers of the world. There is large number of rivers originating from the mighty Himalayas. It's a matter of concern that 600 million people in India face high to extreme water stress and about two lakh people die every year due to inadequate access to safe water[2]. About three-fourth of the households in the country do not have drinking water at their premise. 84 percent rural households do not have piped water access. With nearly 70 percent of water being contaminated, India is placed at 120th amongst 122 countries in the water quality index. India is undergoing the worst water crisis in its history. Critical groundwater resources – which account for 40 percent of our water supply – are being depleted at unsustainable rates. The crisis is only going to get worse. By 2030, the country's water demand is projected to be twice the available supply, implying severe water scarcity for hundreds of millions of people and an eventual ~6 percent loss in the country's GDP[3]. As per the report of National Commission for Integrated Water Resource Development of MoWR, the water requirement by 2050 in high use scenario is likely to be a milder 1,180 BCM, whereas the present-day availability is 695 BCM. The total availability of water possible in country is still lower than this projected demand, at 1,137 BCM. Thus, there is an imminent need to deepen our understanding of our water resources and usage and put in place interventions that make our water use efficient and sustainable. In view of the depletion of water resources, limitation of availability of water and raising demand for

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1 Mandal RB, (2006), Water resource management, concept publishers
2 WRI aqueduct; WHO Global Health Observatory
3 McKinsey & WRG, (2009)'Charting our water future' World Bank; Times of India

potable water, sustainable management of water resources is gaining increased importance and likely to cause formidable challenge to human existence. The rapid growth of population combined with rising levels of consumption and pollution has increased water insecurity in India especially in urban sectors. Climate is also an extremely important determinant of water supply in a region. The global warming leading to climate change can play havoc to the existing human settlements and economic activities. The Indian sub-continent can be extremely vulnerable to the changes in climatic patterns. The major water demand drivers are Agriculture, Domestic, Industries and Energy production. Agriculture is the most intensive water consumer due to the requirement of water for irrigation. Regulation of water consumption is a necessity based on the water availability. It’s a fact that water is a State subject and its optimal utilization and management lies predominantly within the domain of the States.

Statement of the Problem

The dissertation analyses that despite the possession of abundant sources of water in India, a viable policy is required to be in place so that, national survival, inter and intra-state tension and the likelihood of “water wars” are avoided and water security is ensured by the next decade. Water is life sustaining resource for several creatures on the Earth surface but unfortunately the good quality water is scarce. The demand for water in the world has increased three times more in comparison with the growth of population. An increase in awareness is required over the entire world regarding the judicious use and management of water resources. The Planning Commission, GoI has warned that India will face water crisis by 2025. Hence, improved, inclusive, indigenous and scientific methods of water development, storage and suitable water management reforms are required to ensure water security for the country.

Justification of the Study

Water resource is essential for the human society along with the development of other resources. It has been truly said that "nothing will survive in this world without water". The drought from global warming and other environmental issues put enormous pressure on the water resources. 40 percent of the globes population is already short of fresh water and given current trends this will rise to 50 percent by 2030. One of the most important issues that mar bilateral relations among the countries of the subcontinent is water. Hence, the likelihood of tension and conflict emanating from the consumption and distribution pattern of river waters cannot be underestimated. The issues of water distribution and management are bringing not only countries of the region, but also states and regions within provinces into conflict since they are not being settled amicably within a grand framework of riparian states respecting upstream and downstream rights.

Objectives

Against this background, the present study aims:-

- To study the genesis of water security problems faced by India
- To review the water management and development practices in India, and
- To identify robust and implementable methods needed to bring about lasting reforms in water resource management to ensure water security in the future.

Research Questions

This research aims to answer the following questions:-

- What are the existing water resources of India?
- What are the flaws in the existing water resource management, storage and development methods?
- What are the suggested water preservation methodologies?

Limitations

The water resources available in the country are not yet completely mapped. The true status of ground water resources using scientific method of assessment is also not conducted. Water management is often currently viewed as a zero-sum game by states due to limited frameworks for inter-state and national management. This has resulted in seven major disputes regarding the country's rivers, involving 11 states[4]. Hence, the amount of potable water available would be estimation based on the investigation carried out on the regional water availability in the context of rainfall, potentially utilizable surface water and ground-water resources. The study confines itself to analysis of primary and secondary data. It analyses the relevant policies, National Framework Bill and other pieces of data published by Ministry of Water Resources, India and government sources in the developed countries. Based on the findings extracted from secondary data, recommendations are made towards improvements in water management, storage and development methods and changes in the policies to make water management robust towards ensuring water security by next decade.

[4] http://www.Clear IAS.com

Research Strategy and Design

A qualitative approach strategy is adopted to carry out the research. It conforms to basic principles of identification of the problem and establishing a justification for the study with a view to arrive at a specific facet of the problem. The research design is Descriptive and Exploratory in nature. It carried out the content analysis of available literature to understand the present state and policies. The entire study primarily relied on the analysis of secondary data to examine the water preservation methodologies in vogue and its limitations. The relevant Government policies were studied to understand measures being undertaken for water storage and management. Based on the unstructured interviews and discussions held with few key officials involved in policy making in providing water security, areas needing sufficient thrust in our country are highlighted.

Data Source

The data was collected from primary and secondary sources by the following methods:-

- Unstructured Interview with government officials
- Review of books, journals and published articles
- Study of the maps showing the distribution of major river basins and their discharge points across climatic regions
- Study of graphical and tabular representation
- Analysis of survey carried out under NITI Aayog.
- Study of existing policy of government of India towards water management and storage

- Study of the water management and development reforms of the

developed countries

- Study of the reports released by GOI, developed countries and various other organisations

- Analysis of the case studies of developed countries

Literature Review

Some studies were carried out to identify the existing best practices as well as the techniques available to efficiently use water in the region. A brief policy review was also undertaken to provide recommendations. The books that have been reviewed are as follows:-

- ***Ballabh Vishwa, (2008) Governance of Water, Institutional Alternatives and Political Economy, SAGE***. The author highlights that India particularly stands on the brink of an uncertain future, its ever-growing population is putting pressure on its increasingly meagre water resources. The challenges facing water governance in India cannot be addressed in the current policy framework. An oft-quoted, modern adage is that the next major global conflict is over water. In many areas of the world the present is already marked by an uneasy competition among different water users leading to conflicts. The research on the transformation of water governance requires in-depth analysis to make the process more transparent, participatory and accountable to the larger society.

- ***Maestu Josefina, (2013) Water Trading and Global Water Scarcity, International experiences', RFF Press***. The author brings out that water scarcity is an increasing problem in many parts of the world, yet conventional supply-side economics and management are insufficient to deal with it. Water trading is an instrument for conflict resolution, where it may be necessary to reallocate water in the context of increasing scarcity. The role of public sector and institutional reforms required in India on improving efficiency in water management require further study.

- ***Dinesh Kumar. M, (2010) Managing Water, In River Basins, Oxford University Press***. The author highlights that managing water resources effectively is one of India's prime concerns today. He provides an in-depth analysis of existing methods of water management and highlights the gaps in the use of water in various river basins. The kind of interventions that would be needed to avert the nature and magnitude of water scarcity would need further analysis.

- ***Mandal R .B, (2006) Water Resource Management, Concept Publishers***. The author addresses a variety of issues pertaining to water resource utilisation and management, the length of problems of water supply for agriculture and industrial use and the problems and solutions of inter-state river water disputes. The existing water harvesting techniques, sustainability of water resources and help rendered by watershed management and remote sensing is also discussed. The method to generate a realistic scenario for future water demands and assessing the type, nature, and magnitude of scarcity need further investigation.

- ***Mallet Victor, (2017) River of Life, River of Death, The Ganges and India's Future, Oxford University Press***. The author focuses on tracing of river from ancient times to the present day. The pollution that threatens human and animal health in India and around the world is covered and highlight that the same people who adore the river abuse it. The threats facing the Ganges - from pollution, overpopulation, climate change, and often bad policies - are also the severest problems threatening India's progress is discussed. A scientific management is required to minimise river pollution and improve water management and require further analysis.

Chapterisation

The chapterisation of the study is as follows:-

- **Chapter 1 Introduction:** This chapter introduces the study of the subject followed by statement of the problem and justification for the study. Objectives of study and the methodology of study are also spelt out.

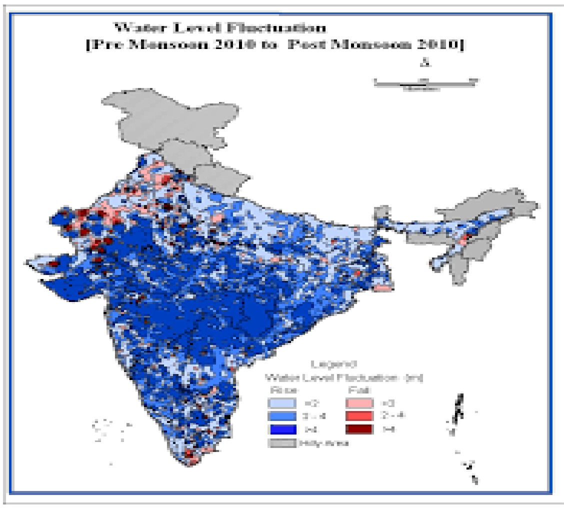
- **Chapter 2 Water Resources in India:** In this chapter, discussion on different types of water resources including rainwater resource and glacial snowmelt water resource is covered to arrive at the health and status of India's water resources. The water development plan is discussed. The water development model is studied. An assessment of sectoral water demand and water balance of the watershed to understand the water stress scenarios based on the available water resource and imposed demand by major sectors is carried out. The estimates of water demand for the three major sectors of agriculture, industries and domestic are analysed. The ultimate water demand is reviewed.

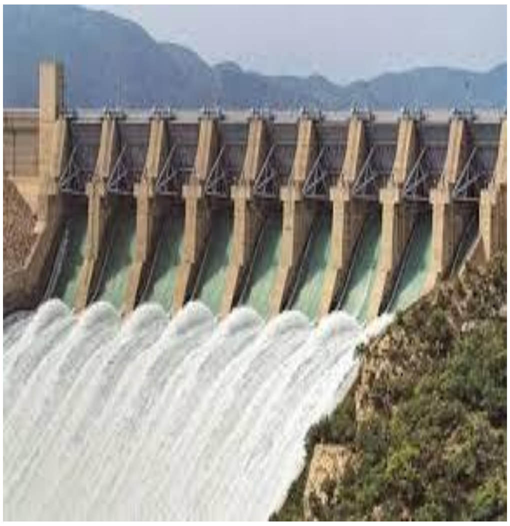
- **Chapter 3 Water Resource Management:** This chapter reviews the flaws in the existing system, paradoxes and contradictions on the existing water resource management methods including surface run-off management, watershed management is also discussed. Conflict between the states and relevant tribunals as well as India's water treaties with neighbouring countries and certain important related issues are brought out. The changes in water stress under climate change scenario are analysed.

- **Chapter 4 Ground Water Management** In this chapter, means to locate new sources of water, rainwater harvesting, ground-water system management and methods of groundwater recharging and storage are discussed. Some of the international best practices on efficient water use in various sectors is reviewed and presented to explore the opportunities for saving water in India in various sectors. Additionally, regulatory and institutional level recommendations are also provided with respect to water utilisation and efficient management of water resources across the sectors. An assessment of water stress for future scenarios is also carried out.

- **Chapter 5 Water Security: Awareness and Responsibilities:** In this chapter existing lack of commitment / concern and its fallout on water security is discussed. Water is a social issue and societal response to water development is a requirement. A strong awareness campaign on water related aspects through all means of mass communication forming the background reviews responsibility on water related matters.

- **Chapter 6 Conclusion and Recommendations:** In this chapter suggested policy along with recommendations is dwelled upon. In the current Indian context, the biggest challenges regarding water management are to meet the growing demands of various sectors such as Agriculture, Industries, urban water drinking needs, sustaining ecology and environment. The chapter offers reasoned recommendations for long term water management to achieve self-sufficiency and water security.


Water Level Fluctuation
[Pre Monsoon 2010 to Post Monsoon 2010]
Legend
Water Level Fluctuation (m)
Rise
Fall
2 - 4
2 - 4
Hilly Area



CHAPTER II

WATER RESOURCES IN INDIA

Water is one of the most important natural resource, but its availability is limited and the efficient use of which is of increasing importance as demand is exceeding the availability. Water is available in the atmosphere, the ocean, on land and within the soil. They can be categorised as the Surface water resource, the Ground water resource and precipitation. The surface water subsystem comprises rivers, lakes, ponds, springs, streams, dams and other water storage resources. While ground water is a significant water resource, large amounts of human efforts and peripheral activities are required to tap this resource. At present more than 70 percent of the population uses ground water for its domestic needs and more than half of irrigation is provided from this source.

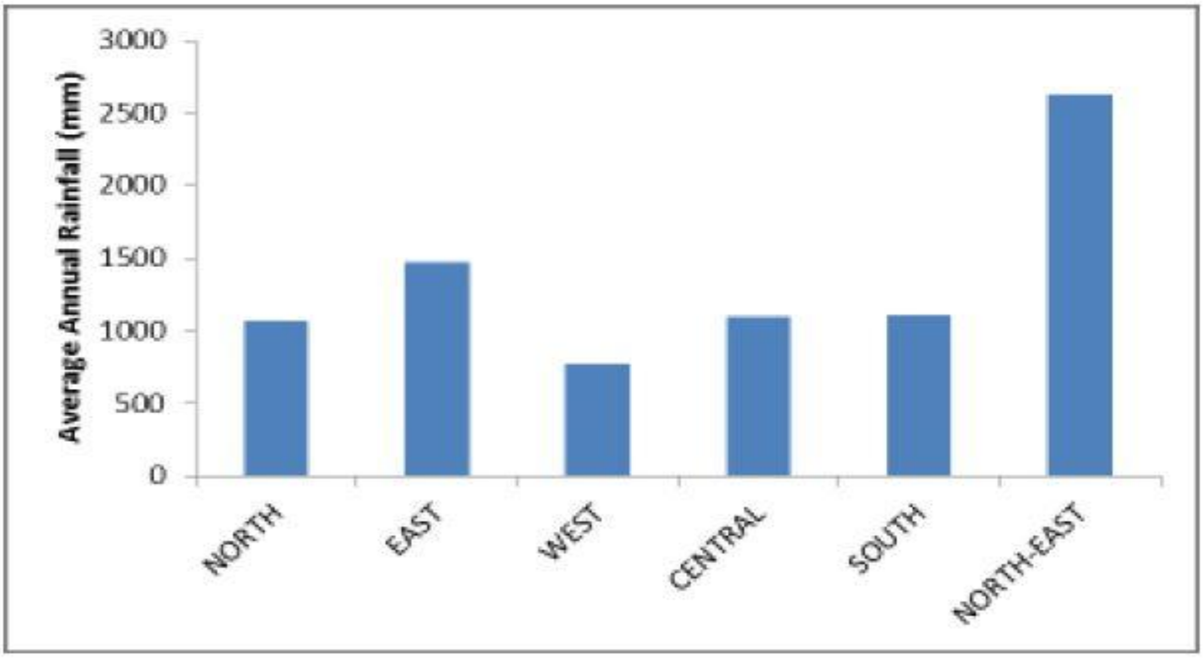
Precipitation occurs when atmospheric moisture becomes too great to remain suspended in clouds. It denotes all forms of water that reach the earth from the atmosphere, the usual forms being rainfall, snowfall, hail, frost and dew. Once it reaches the earth's surface, precipitation can become surface water runoff, surface water storage, glacial ice, water for plants, ground water or may evaporate and return to atmosphere. Ocean evaporation is the greatest source of precipitation. The annual average rainfall in the Indian terrain is a healthy 120 cm much more than the world average rainfall of 100 cm.[5] About 90 percent of the water that flows in rivers of India is a result of monsoonal rainfall between June to September and snowfall in the Himalayan region during short winter season of mid December to mid February. Thus the paradoxical situation is that the Indian terrain receives almost the whole quota of

[5] Sarvotham H,(2004), Water: Resource Augmentation, Management and Policies, p21.

rain for the full year in a short period of four months. That indeed is the reason for water resource management becoming a complex affair in India, for, the rainfall that is received during this short period unevenly distributed in various segments of the country. The variation in average rainfall in different regions is depicted:

Figure 2.1

Variation in average rainfall in different regions



Source: Report Assessment of Water Foot Prints of India's Long term energy scenarios, (TERI), 2017

The average annual precipitation in volumetric terms is 4000 BCM. The average annual surface flow out of this is 1869 BCM, the rest being lost in infiltration and evaporation. This is the average water resources potential in India. But the amount of water that can be actually put to beneficial use is much less due to severe limitations posed by physiography, topography, inter-state issues and the present state of technology to harness water resources economically. According to Central Water Commission, utilizable surface water resources in the country are about 690 BCM (about 36percent of the total water). This is the amount of water that can be purpose fully used, without any wastage to the sea, if water storage and conveyance structures like dams, barrages, canals, etc. are suitably built at requisite sites. Additionally, the potential of dynamic or *rechargeable* ground water resources of our country has been estimated by the Central Ground Water Board to be about 432 cubic km. The average water resource in India is depicted below:

Table 2.1

The water resources of India

Average Annual Precipitation Volume	4000 BCM
Natural Runoff (Surface water and ground water)	1869 BCM
Estimated utilizable surface water potential	690 BCM
Ground Water Resources	432 BCM

Source: Report Assessment of Water Foot Prints of India’s Long term energy scenarios, (TERI), 2017

While rain is a vital source of water for almost the whole of the Indian peninsula, the snowmelt from the glaciers of the Himalayan belt is a significant contributor to the water source to the valley parts and the foothill region of the Himalayas. The Himalayan glaciers have enormous amount of water contained in the form of snow or ice or what are known as snow packs. These snow packs melt in summer season contributing considerable volume of water in the perennial rivers flowing through the Himalayan mountain chain and its foothill belt.

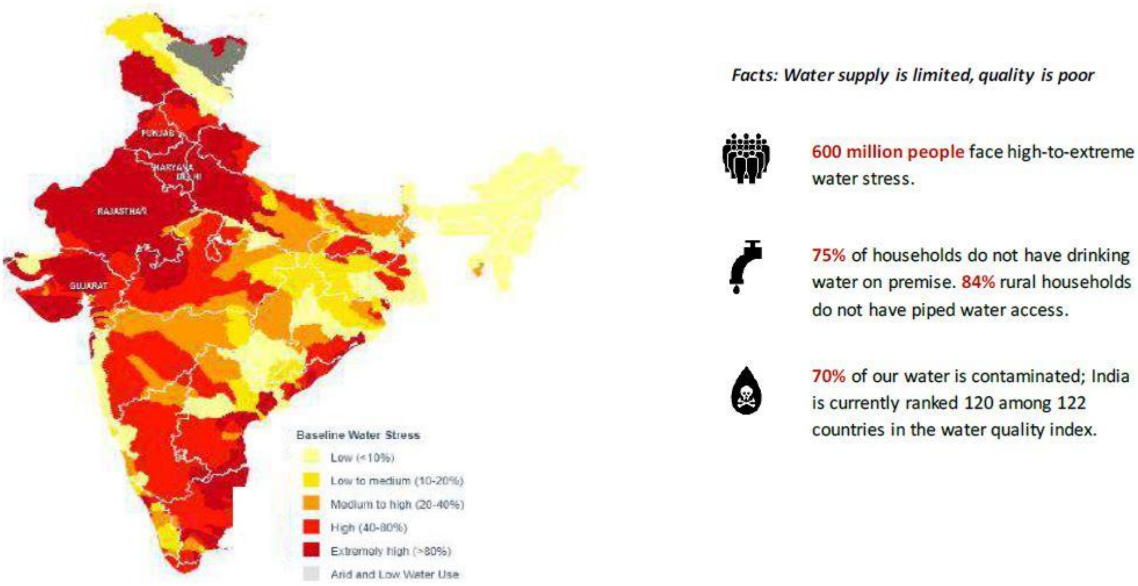
While an exact value of water resources of the country is a difficult task, estimates of the water resources has been done in a comprehensive manner by the Ministry of Water Resources. An analysis of the resources gives a very rosy picture, however the complexities involved in harnessing the resources in an optimum manner is what is causing nightmares to the ministry. Depending only on rainwater resources for all our activities will mean our entire dependence on the forces of nature over which we do not have any control.

One fact that would not evoke any debate is that our surface water and groundwater resources have certainly depleted over a period of time on account of extreme stress we have mounted over these two resources. We have abused and plundered the pristine rainwater resources in the past and we cannot afford to continue this way. We have to find out ways to identify suitable substitutes for the rainwater that is now misused.

New research has shown that India is undergoing worst water crisis n the world. Already, more than 600 million people are facing acute water shortages. Critical groundwater resources – which account for 40percent of our water supply – are being depleted at unsustainable rates. The base line water stress in various regions of India and viability of water is depicted below:

Figure 2.2

The base line water stress in India



Source: Composite Water Management Index by NITI Aayog, June 2018

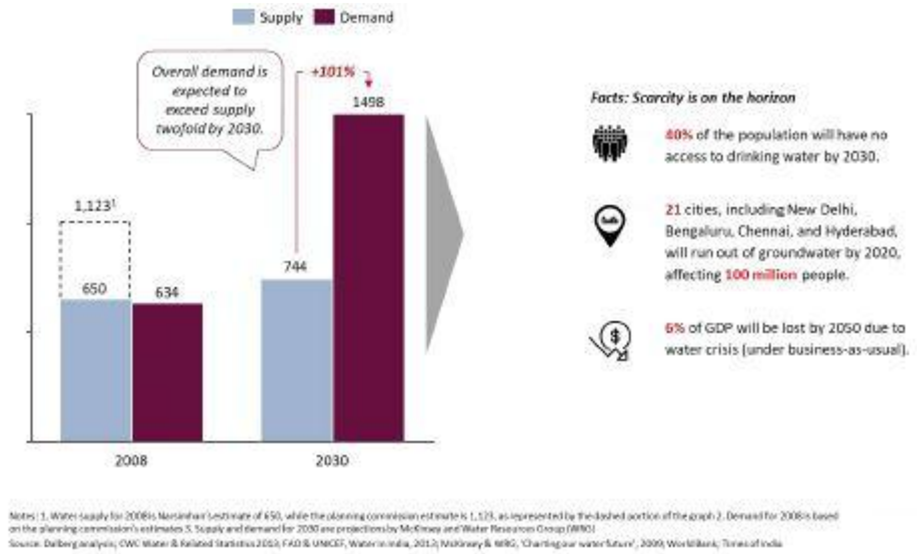
Droughts are becoming frequent in India and some of the regions are more prone than others creating problems to rain dependent agricultural crops and farmers livelihood. No settlement is on the horizon regarding Water disagreements between states. Currently there are seven major disputes raging[6], pointing to the fact that there is a requirement of stronger frameworks and institutions in place for national water governance. However due to the multiplication of population the demand is growing at a rapid rate. The estimates indicate that India's water demand will exceed supply by a factor of two by 2030, with severe water scarcity in the country. The forecast for demand and water supply in India is depicted[7]

[6] Ibid

[7] Demand for 2008 is based on the planning commission's estimates 3. Supply and demand for 2030 are projections by McKinsey and Water Resources Group (WRG), Composite Water Management Index by NITI Aayog, June 2018

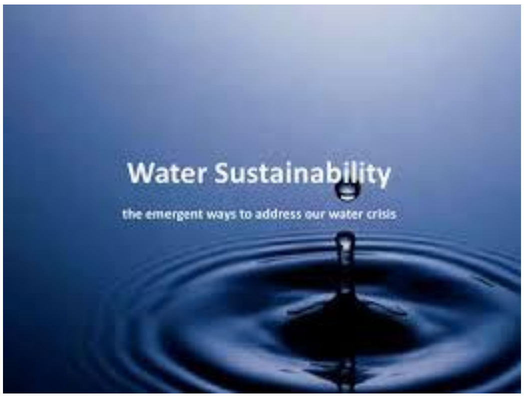
Figure 2.3

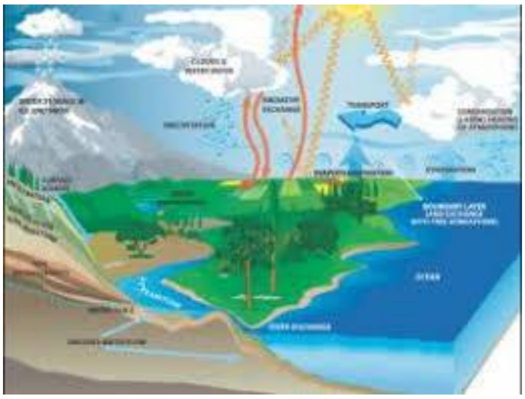
Demand and supply of water in India (forecast) in BCM.

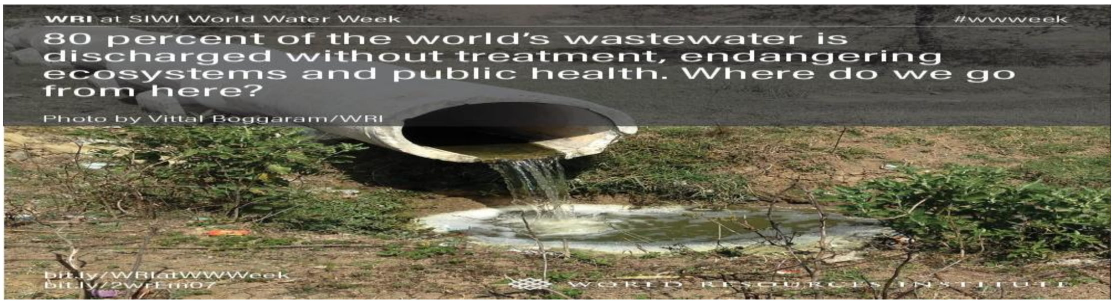


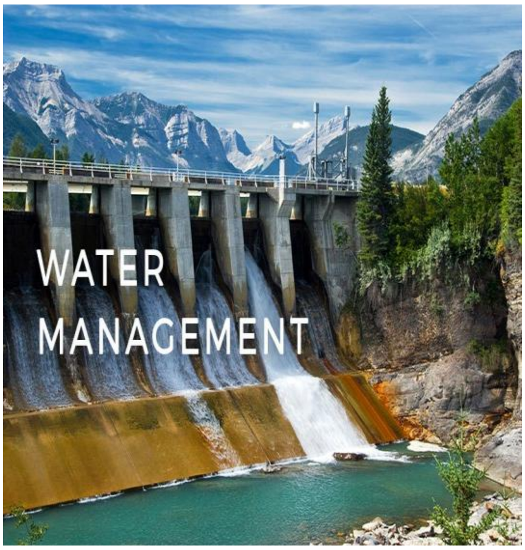
Source: Composite Water Management Index by NITI Aayog, June 2018

The new research by National Geographical Research Institute has shown that the largest groundwater depletion in the world is happening in northern India. Delhi is the epicentre of this fast developing crisis. The main reason is due to the faster rate at which groundwater is being pumped out as compared to groundwater getting recharged. The level of water in the underground aquifers in the region is also falling at a rapid rate. Drying up of groundwater by using bigger pumps from deeper bore wells is also causing large scale contamination of water. Hence, there is a requirement to find and locate new aquifers and new source of groundwater using latest technology like Heli-borne technology.


Water Sustainability
the emergent ways to address our water crisis




WRI at SIWI World Water Week
#wwweek
80 percent of the world's wastewater is discharged without treatment, endangering ecosystems and public health. Where do we go from here?
Photo by Vittal Boggaram/WRI


WATER
MANAGEMENT

CHAPTER III

WATER RESOURCE MANAGEMENT

Management of water resources implies making the best use of available water resources for human requirements while preventing and controlling its depletion and degradation and also developing it in view of the present and future requirements. Efficient distribution of scarce water among multiple users poses a major challenge. Mismanagement of water in deficient areas is also quite common. Hence, Water resource management have to be understood in terms of technological and engineering requirements. We have not mapped our water resources properly. The exact status of our ground water resources is known. We have enormous satellite technology to look deep into the earth and recently an exercise was carried out for knowing our ground water resources. Remember the last time two nations went to war over water? Probably not, since it was in Mesopotamia 4,500 years ago. But today, as demands for water hit the limits of a finite supply, conflicts are spreading within nations.

Water security is emerging as an increasingly important and vital issue for the Asia-Pacific region. Perhaps no other resource, other than oxygen, is so intricately linked to human health and survival. A renewable but not infinite resource, fresh water is becoming increasingly scarce. The amount available to the world today is almost the same as it was when the Mesopotamians traded blows, even as global demand has steadily increased. With increase in population the demand for water is increasing day by day. Moreover, unlike oil and most other strategic resources, fresh water has no substitute in most of its uses. It is essential for growing food, manufacturing goods and safeguarding human health. Many South Asian countries are beginning to experience moderate to severe water shortages, brought on by the simultaneous effects of agricultural growth, industrialization, and urbanization. In recent years, moreover, evidence indicates that water security is becoming increasingly affected by erratic weather patterns, most notably the *El Nino* and *La Nina* weather phenomena.

Several countries in South Asia have experienced droughts of such severity that they have caused food shortages and have threatened the long-term food supply. In the future, climate change may produce even more erratic weather and result in similar crises. Another concern in the region is growing competition over shared water resources. India, Pakistan, Nepal, Bhutan and Bangladesh share water resources and depend on mutual cooperation. Conflict over freshwater has strained relations between India and Bangladesh, as well as India and Pakistan.[8] In the future, diminishing and degraded freshwater resources could lead to internal instability in many nations, and possibly even spark interstate conflict.

Inter – State Water Disputes

In India there are significant areas of water scarcity with one-third of its 570,000 villages declared as being water deficient. This is due to uneven distribution of water resources. The North and East are water rich while South and West are water deficient. The distribution of rainfall is also highly uneven with 100 mm in west Rajasthan and 11,000 mm in Meghalaya[9]. The combined effect of such factors is uneven water availability from basin to basin. Hence, the Inter- state water disputes are fast emerging as a serious national problem in India. These disputes are very complex in character and in spite of sincere efforts by all concerned some disputes

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[8] Shri B G Verghese, Indus Water Treaty, USI Journal Jun 2005.
[9] Ballabh Vishwa, Governance of Water, Institutional Alternatives and political Economy (2008), SAGE

evade solution and remain festering for a long time. The deficiencies in the legal process are one of the reasons preventing the ultimate settlement of the dispute. Even if a final agreement is reached there is no guarantee that the conflict will not surface again. This is mainly due to the cyclic nature of the inter-state water conflicts. The presence of a permanent monitoring body would be essential to look into the matter of implementation of the agreements as well as monitoring the changes by constantly collecting data like changes in the river basin over a period of time, which would be useful in settling future conflicts over water. Also, the involvement of civil society should be encouraged in the dispute resolution process to act as a counter-weight against the political interference.

Water Demand

Water demand assessment for different water users is important to understand the stress between the sectors for limited water resource. The assessment has to cater for sectoral water demand and water balance of the watershed to understand the water stress scenarios based on the available water resource and imposed demand by major sectors. The four major components are Consumption, Production, Water Demand and Water Supply. The major water user sectors are agriculture, domestic and industries.

Agriculture Water Demand

Agriculture sector is the most intensive water user due to requirement of water for irrigation. Different crops have different water requirement during their development stages. The term water requirements of a crop means the total quantity of all water and the way in which a crop requires water, from the time it is sown to the time it is harvested. The water requirement of crop varies with the crop as well as with the place. The same crop may have different water requirements at different places; depending upon the climate, type of soil, method of cultivation and useful rainfall. The requirement of water for the growth of the plant depends both on the transpiration from the plant and evaporation from the surface. Thus, key drivers for irrigation water requirement are area under irrigation, type of crop and growth period of crops. In India, rabi season crops except in Tamil Nadu are considered as lean period crops. In Tamil Nadu, kharif season crops are lean period crops. Paddy and wheat are the two distinct kharif and rabi crops being grown in the country respectively. Every region grows either/ both of them. Area under paddy and wheat cultivation is distributed as 60:40, in the country with eastern region having maximum area under paddy cultivation and northern region under wheat cultivation.

However, with reference to irrigated cultivation, northern region has maximum area under irrigation of both paddy and wheat. Accordingly, agricultural water requirement for both kharif and rabi season is highest in northern region as compared to other regions of the country, and the same is distributed as 58 percent and 42 percent respectively. Southern region is another important cultivator of irrigated paddy and so its kharif water requirement for agriculture is higher than other regions, except northern. In western region, wheat cultivation is almost double its paddy cultivation, and so lean period water requirement in this region is 2nd highest after northern region. At the national level, agricultural water requirement is distributed between peak and lean period as 56 percent and 44 percent respectively.

Domestic water demand

Domestic water demand majorly comprises of requirement of water for drinking, cooking, bathing, washing, flushing of toilet, gardening, etc. Also, domestic water demand includes water demand for both – human beings and livestock. Domestic water demand is regulated primarily by the total number of people (or livestock) in an area and their daily water requirement. As water consumption in rural and urban areas is different, percentage of urbanisation in an area also has a significant impact on its total water demand. Domestic water demand is almost uniformly distributed throughout the country, as no reliable estimates of seasonal variation were available. However, as per general understanding it may be considered that domestic water requirement is higher during the summer season of lean period and lesser during the peak monsoon period, thereby increasing the stress on available water resources. Hence, domestic water requirement for 8 and 4 months of lean and peak seasons respectively can be safely distributed as 70:30 percent of the annual requirement. But still, domestic water requirement follows the annual pattern of distribution, itself.

Industrial Water Demand

Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. Production system of water guzzling industries like textile, pulp and paper, cement, fertilizer and iron and steel, is not governed by seasonality and so industrial water requirement is uniformly distributed over lean and peak periods. As such industrial water requirement follows the annual pattern of distribution.

Water for Energy Production

Similar to domestic water requirement, water for energy production is also distributed uniformly throughout the year. Data from Central Electricity Authority indicates a variation of 1-5 percent in amount of electricity generation from power plants during the year, with minimum production during July and August months of peak season. Thus, electricity production is more during the lean period than the peak season, and so the water consumption for electricity production can be distributed as 70:30 percent of annual requirement during the 8 and 4 months of lean and peak seasons, respectively. Total water requirement for the production of energy in the western region is almost equivalent to its industrial water requirement. 87.5 percent of water for energy in the region is consumed for production of electricity and remaining for the exploration and refining of petroleum. With reference to water consumption for energy production, major states of the region can be ranked as Maharashtra > Gujarat > Rajasthan, however, the top two states are responsible for consumption of almost 84 percent of total water.

Waste Water Treatment

. While urban water access is high on average, significant gaps remain across the country, and waste water treatment remains stuck at the national average of ~33 percent. Most states report a high percentage of urban population having access to drinking water, except for the North-Eastern and Eastern regions, with Bihar, Jharkhand, Assam, and Nagaland reporting less than half of the urban population having access. Significant gaps remain across the country though, as even states with the largest urban areas Maharashtra, Tamil Nadu, and Kerala are only able to provide drinking water to 53-72 percent of their massive urban populations. Waste water treatment capacity and actual treatment vary widely, but 70 percent of states treat less than half of their waste water and the median state treated ~33 percent of its water in FY 16-17, indicating ample room for improvement. It is imperative for the country to boost treatment of urban waste water, both to ensure that downstream areas are not contaminated, and to enable the reuse of water. By reusing water, the country can significantly increase the utility gained out of all available water. The reused water can also be used towards meeting the country's vast agricultural demand. Israel offers the perfect example as the global leader in reusing water—it reuses 94 percent of all water, with the majority being used to meet 50 percent of the country's agricultural water demand. But the fact is a majority of towns and cities in India have either no sewerage and sewage treatment facilities or the treatment facilities are highly inadequate. Sources of wastewater include homes, farms, factories, hospitals and businesses. Feaces and urine from both humans and animals carry many disease causing organisms. Wastewater may also contain harmful chemicals and heavy metals known to cause a variety of health problems. Disease-causing organisms (pathogens) from patients at hospitals can enter wastewater. Wastewater may also carry carcinogens increasing the risk of cancers among vulnerable people who could directly or indirectly come in contact with such wastewater.

When untreated wastewater mixes with groundwater it can create significant health risks to people who have suppressed immune systems. Children, the elderly, and the poor are also significantly more at risk than the general population. So, it is pertinent to properly treat wastewater before it runs down the water stream. The sludge removal, treatment and handling have been the most neglected areas in the operation of the STPs in India. Due to improper design, poor maintenance, frequent electricity break downs and lack of technical manpower, the facilities constructed to treat wastewater do not function properly and remain closed most of the time. Utilization of biogas generated from UASB (Up flow Anaerobic Sludge Blanket) reactors or sludge digesters are also not adequate in most of the cases. Water management in South Asia involves far more than rivers and aquifers flowing across national boundaries. However there are a few factors which must be kept in mind before discussing water resource management.

- **Water Stress and Water Scarcity.** With regard to water supplies, there are the problems of 'water stress' and 'water scarcity'. Water stress occurs when a country's annual water supplies drop below 1,700 cubic meters per person. When these levels reach between 1,700 and 1,000 cubic meters per person, occasional water shortages are likely to occur. However, when water supplies drop below 1,000 cubic meters per person, the country faces water scarcity which can threaten food production, undermine economic development, and harm ecosystems. Today, more than 31 countries around the world, representing about 8 percent of the world population, are facing chronic freshwater shortages (thus reaching the scarcity stage), and this number will likely grow to 45 countries by the year 2025.[10]
- **Access and Availability.** The world's freshwater supply is finite. Most of the world's water, about 97.5 percent exists as salt water in the oceans and seas. Of the world's 2.5 percent of freshwater, roughly 99 percent is either trapped in glaciers and ice caps, held as soil moisture, or located in water tables too deep to access. Thus, only about one percent of the world's total freshwater supply is readily available for consumption by humans, animals and for irrigation. When analyzing freshwater and its relationship to human consumption, it is useful to

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[10] World Water forum address at Marrakesh, (1997), Jim Yongjain, Vision for Water, Life and the Environment

delineate two concepts: availability vs access. Availability refers to the physical presence of adequate water supplies, whereas access refers to the ability of people within a particular country or region to actually receive or gain access to clean freshwater. Obviously, these are two distinct types of problems, although they can both be present in a region experiencing water stress or water scarcity. Availability may be more dependent on physical or environmental factors (i.e., the geography of a particular country or climate change, etc.), whereas access may be more dependent on social or political factors (i.e. how much of a country's agricultural sector is dependent on irrigation, or how effective a country's municipal water supply is, etc).

- **Water Quality Issues**. Contamination can enter the water bodies through one or more of the following ways:
  - ✓ **Direct Point Sources**: Transfer of pollutants from municipal industrial liquid waste disposal sites and from municipal and household hazardous waste and refuse disposal sites.
  - ✓ **Diffuse Agricultural Sources**: Wash off and soil erosion from agricultural land carrying materials applied during agricultural use, mainly fertilisers, herbicides and pesticides.
  - ✓ **Diffuse Urban Sources**: Run off from city streets, from horticultural, gardening and commercial activities in the urban environment and from industrial sites and storage areas. Water quality issues needing to be addressed with respect to different water bodies are presented below.
  - ✓ **Pollution in Rivers.** Change in Physical Characteristics Temperature, turbidity and total suspended solids (TSS) in rivers can be greatly affected by human activities such as agriculture, deforestation and the use of water for

cooling. For example, the upward trend in soil erosion and the related increase in TSS in rivers can be seen in most of the mountainous regions in India.

- ✓ **Contamination by Faecal and Organic Matter,** In India faecal contamination is still the primary water quality issue in rivers, especially where human and animal wastes are not adequately collected and treated. Although this applies to both rural and urban areas, the situation is probably more critical in fast-growing cities.

- ✓ **The Release of Untreated Domestic or Industrial Wastes High in Organic Matter into Rivers.** This results in a marked decline in oxygen concentration (sometimes resulting in anaerobic conditions) and a rise in ammonia and nitrogen concentrations, downstream of the effluent input. The most obvious effect of the release of organic matter along the length of the river is the depletion of oxygen downstream of the discharge as shown by the so-called 'oxygen-sag curve' which plots dissolved oxygen concentration against distance. Industrial activities which discharge large organic loads include, pulp and paper production and food processing. Faecal matter affects the use of water for drinking water source or bathing water, as well as ecological health of river.

- ✓ **Toxic Pollutants.** Organics and Heavy Metals organic pollutants (Mostly chemicals manufactured artificially by man) are also becoming an important water quality issue. They enter rivers as: point sources directly from sewers and effluent discharges (Domestic, Urban and industrial sources) diffuse sources from the leaching of solid and liquid waste dumps or agricultural land run off indirectly through long-range atmospheric transport and deposition. Uncontrolled discharge of industrial wastewater often causes pollution due to toxic metals. Other sources of metal pollution are leachates from urban solid waste landfills and mining waste dumps. Rivers such as the Yamuna, which pass through large towns and cities, are often badly affected with organic pollutants. Another example is that of Damodar River which is polluted with heavy metals arising mostly from electroplating, tanning and metal based industries.

✓ **River Eutrophication**. During the 1950s and 1960s, eutrophication (nutrient enrichment leading to increased plant arid algae growth) was observed mostly in lakes and reservoirs. Since the 1970s the increasing levels of phosphates and nitrates entering rivers, particularly in developed countries were largely responsible for eutrophication occurring in running waters.[11] In India isolated reports have appeared for some river reaches especially in plains around agriculture tracts of land. In small rivers eutrophication is said to promote macrophyte (large plants) development, whereas in large rivers phytoplankton (algae) are usually more dominant than macrophyte. In such situations the chlorophyll concentration of the water may reach extremely high values due to the fact that this pigment is present in all plants eutrophication can result in marked variations in dissolved oxygen arid pH throughout the day. The changes in water quality caused by eutrophication can be a major cause of stress to fish due to the release, at high pH, of highly toxic gaseous ammonia and depletion of oxygen after sunshine hours.

[11] Water Quality Issues at http://www.mowr.nic.in.

✓ **River Salinisation**. Increased mineral salts in rivers may arise from several sources:

- Pollution by mining waste waters
- Pollution by certain industrial waste waters
- Increased evaporation in the river basin (mainly in arid and semiarid regions) Industrial and mining waste pollution results in increase in specifications. Evaporation however, increases the concentration of all ions.

✓ **Changes in River Hydrology**. Many human activities, directly or indirectly, lead to modifications of river channels, which can, in turn, induce changes to the aquatic environment. Major modifications to river systems include changes to depth and width for navigation, creation of flood control ponds, creation of reservoirs for drinking water supply, damming for hydroelectric power generation and diversion for irrigation purposes. All of the above affect the hydrology and related uses of the river system and so have a great potential to affect water quality. It must be remembered, however, that not all such water quality changes are necessarily detrimental.

✓ **Groundwater Pollution.** Unsewered Domestic Waste -Under certain hydro geological conditions, this domestic waste can cause severe groundwater contamination by pathogenic bacteria, nitrate and other pollutants. Unsewered waste normally means septic tanks or pit latrines of the ventilated, dry or pour-flush types. There are important differences between the two in relation to the risk of groundwater contamination. Septic tank soak ways discharge at higher levels in the soil profile than pit latrines and such conditions are preferable as far as the elimination of bacteria is concerned. Pit latrines are often deep excavations (to allow a long useful life) and the soil may be entirely removed thus offering less opportunity for bacterial death.

Further the loading from septic tank soak ways is likely to be less than for some of the pit latrine types. Septic tanks are lined and their solid effluent of high nitrogen content is periodically removed, whereas most pit latrines are unlined and the solid material remains in the ground. The impact of unsewered domestic waste is felt particularly in relation to the contamination of groundwater drinking water supplies. In India, the percentage of sewered population is nearly negligible in most of the rural areas and is quite meagre (0 to 50 percent) in most medium and small towns. As a result, the contamination of groundwater by pollution from unsewered areas is one of the most important environmental problems facing the country.

- ✓ **Disposal of Liquid Urban and Industrial Waste**. Methods of wastewater disposal include infiltration ponds, spreading or spraying on to the ground surface and discharge to stream or dry stream beds, which if not carefully regulated may provide a rapid pollution pathway to underlying, shallow aquifers. In some areas, deep soak ways or abandoned wells are used for the disposal of liquid domestic, industrial or farming wastes into aquifers. Lack of monitoring, supervision or management adds to the problem. Even if the intention is to dispose of the waste at depth, improper sealing or corrosion of well linings often produces leaks and subsequent pollution of the shallow groundwater which is used for water supplies. In urban areas covered by sewerage systems, an economical and common method of partial treatment of sewage is wastewater stabilisation by retention in shallow oxidation lagoons before subsequent discharge into rivers or onto land for irrigation systems. These lagoons are often unlined and, if constructed over coarse-textured soils, may have high rates of seepage loss. Further, the use of such effluent in irrigation may also lead to similar problems. Most of the unplanned industrial complexes and scattered industrial units in urban areas and the agricultural-related industries in remote villages are good examples of this type of pollution.

- ✓ **Disposal of Solid Domestic and Industrial Waste**. The most common method of disposal of solid municipal waste is by deposition in landfills. In order to minimise the impact of such landfills on groundwater quality and the environment in general it is necessary to properly design and build these facilities to prevent pollution and put in place strict management controls to ensure they are operated correctly. Unfortunately this is rarely done as few towns and industries in the country make the necessary effort to ensure that their solid waste is treated or disposed of in a proper manner. The principal threat to groundwater comes from inadequately controlled landfills where leachate generated from the fill material is allowed to escape to the surrounding and underlying ground. The chemical composition of such leachate depends on the nature and age of the landfill and the leaching rate. Most leachates emanating from municipal solid wastes are not only high in organic content but also contain some toxic material. Leachates from solid wastes of industrial origin, however, often contain a much higher proportion of toxic constituents, such as metals and organic pollutants. The treatment of leachate is the only solution.

✓ **Effect of Cultivation with Agrochemicals.** Agricultural land use and cultivation practices have been shown to exert major influences on groundwater quality. Under certain circumstances, serious groundwater pollution can be caused by agricultural activities the influence of that may be very important because of the large areas of aquifer affected. Of particular concern, in India, is the leaching of fertiliser chemicals (e.g., nitrate) and pesticides from regular intensive cultivation of crops. The impact of cultivation practices on groundwater quality is greatest, as are most anthropogenic effects, where relatively shallow, unconfined aquifers are used for potable supply.

In India, a high proportion of the rural population in agricultural areas obtain their domestic water supplies from shallow, private bore holes, which suffer the impact of nitrate pollution to a much greater extent than the deeper, public supply aquifers utilised for urban water supply. These deeper aquifers can also be affected by nitrate contamination although this pollution often takes much more time to percolate to these depths. Much less attention has been given in this country to the leaching of pesticides from agricultural land to the underlying groundwater in spite of the dramatic increase in the use of pesticide formulations over the last years. There are currently few laboratories with the capability of analysing pesticides.

✓ **Salinity from Irrigation.** Increasing salinity resulting from the effects of irrigated agriculture is one or the oldest and most widespread forms of groundwater pollution. It is caused by the dissolved salts in irrigation water being deposited following evaporation of the water. The addition of further excess irrigation water merely leaches salts from the soil and transfers the problem to the underlying groundwater.

✓ **Mining Activities.** A range of groundwater pollution problems can be associated with mining activities. The nature of the pollution depends on the materials being excavated and extracted. Both surface and underground mines usually extend below the water table and often dewatering is required to allow mining to proceed. The water pumped either directly from the mine or from specially constructed bore holes, may be highly mineralised and its usual characteristics include low pH (down to pH 3) and high levels of iron, aluminium and sulphate. Disposal of this mine drainage effluent to surface water or groundwater can cause serious impacts on water quality for all uses. Pollution of groundwater can also result from the leaching of mine tailings and from settling ponds and can, therefore, be associated with both present and past mining activity.

✓ **Geological Formations.** Groundwater in certain geological formations may not be of desired quality for specific uses. Naturally occurring fluorides, arsenic and salinity are known to adversely affect the quality of water for drinking water supplies.

✓ **Lakes and Reservoirs Pollution Pathways.**The following pathways, in addition to the ones mentioned above, assume special significance in the case of lakes and reservoir pollution;

- **Riverine sources**: Pollutants in solution in the inflow or adsorbed onto particulate matter, or both. The cumulative input is the sum of contaminants from all of the rivers draining the watershed into a lake. Groundwater sources: groundwater systems polluted from point and diffuse sources (noted above) flowing into rivers, and directly into lakebeds.

- **Atmospheric sources**: Direct wet and dry atmospheric deposition of contaminants to the lake surface and wash off of similar pollutants from the land. This latter process is defined as secondary cycling.

In addition to the above, lakes serve as traps for pollutants carried by rivers and groundwater draining the watershed. The pollutant concentration in the lake usually builds up due to evaporation of water from the lake's surface unless there is a natural flushing with good quality water.

✓ **Lake Eutrophication.** It is the biological response to excess nutrient input to a lake. The production of biomass and its death and decay results in a number of effects, which individually and collectively result in impaired water use. The most important of these effects are decreased dissolved oxygen levels, release of odorous compounds (e.g. H_2S) and siltation. Many important lakes in India (e.g., Hussein Sagar (Hyderabad), Nainital (Uttar Pradesh) and Dal (Jammu and Kashmir) have reportedly progressed to advanced eutrophication levels.

✓ **Lake Acidification.** One of the major issues related to lakes in particular, and to freshwaters in general, is the progressive acidification associated with deposition of rain and particulates (wet and dry deposition) enriched in mineral acids. The problem is characteristic of lakes in specific regions of the world, which satisfy two major critical conditions: the lakes must have soft water (i.e. low hardness, conductivity and dissolved salts) and be subjected to 'acid rain'. To date, Lake Acidification has not been reported as a problem in India.

- ✓ **Bioaccumulation and Bio magnification.** The processes of bioaccumulation and bio magnification are extremely important in the distribution of toxic substances (discharged in waste effluents) in fresh water ecosystems. The concentration of pollutants within the organism due to bioaccumulation and bio magnification depends on the duration of exposure of the organism to the contaminated environment and its toxic level in the food chain. Several fold increases in trace contaminant concentrations have been commonly observed in lakes and estuarine environments.

The rapid pace of urbanisation, industrialisation as well as agricultural activities has made environmental pollution a growing concern globally. Off all the receptor systems exposed to the contaminants, ground water has received little attention in the past because of the common belief that ground water was pristine. Ground Water Pollution is usually traced back to four main origins industrial, domestic, agricultural and over exploitation. The last category mainly accounts for sea water intrusion. Studies carried out in India reveal that one of the most important causes of ground water pollution is unplanned urban development without adequate attention to sewage and waste disposal. Industrialisation without provision of proper treatment and disposal wastes and affluent is another source of ground water pollution. Excessive application of fertilizers for agricultural development coupled with over-irrigation intrusion due to excessive pumping of fresh water in coastal aquifers is also responsible for ground water pollution.

Ground Water Pollution & Hazards Scenario in India

With the declared objectives of providing at least the basic amenities there has been a tremendous development in India, in the agriculture and industrial sector, with concomitant pressure on the fresh water resources. The waste generated by anthropogenic activities has not only polluted the environment as a whole but had a particular detrimental effect on the quality of aquatic-environment too. Leachates from compost pits, animal refuse of garbage dumping grounds nutrient enriched return irrigation flows seepage from septic tanks, seepage of sewage etc. has adversely affected the ground water quality in several parts of India. The rate of generation of wastewater in India during 1981 was estimated to be 74,529 million litres/day i.e. about $27km^3$ annually, which poses a perennial danger to the potable ground water resource.

The gravity of situation can be judged from the act that in spite of sewage treatment plant, Delhi discharged 100 million gallon of untreated sewage into the Yamuna. The problem is likely to compound further with increasing rate of wastewater generation which is estimated about $40km^3$ (110,000 million litre/day) annually by the year 2020 when the population is estimated to be around ten million. Solid waste disposal is also not lagging behind in adding to ground water pollution problem. With increase of human and livestock population the quantum of waste produced has increased tremendously. The estimated annual waste production from these sources is around 2000 million tons. Studies on chemical composition of ground water in such zone have revealed that in many cases a high concentration of Nitrate Potassium and even phosphate (total phosphate) are present in contrast to their virtual absence or low concentration (No.3 and K less than l0 mg/l) in semi-confined and aquifers. Unsystematic use of synthetic fertilizers couple with improper water management practices have resulted in deterioration of ground water quality in many parts of the country.

In case of industrial units, effluent in most of the cases are discharged into pits, open ground, or open unlined drains near the factories, thus allowing it to move to low lying depressions resulting ground water pollution. The industries which are burgeoning at terrifying fast rate, daily produce about 55000 million M^3 of wastewater per day, out of which 68.5 million M^3 is discharged into river streams. Thus the magnitude of damage caused to our water resources can be estimated from the fact that about 70 percent of rivers and streams in India contain polluted water.

The incidence of ground water pollution is highest in urban where large volume of waste are concentrated and discharged into relatively small areas. The ground water contamination, however, is detected only some time after the subsurface contamination begins. Thirteen states in India have been identified as endemic to fluorosis due to abundance in natural occurring fluoride bearing minerals. These are Nalgonda, Rangaraddy district in A.P. Banskantha, Kutch, Amroli in Gujarat, Hissar, Kaithal, Gurgaon in Haryana, Angul Bolengir, Phulbani in Orissa, Bhatinda, Sangrur in Punjab, Ajmer, Bikaner, Pali, Nagaur, Sirohi in Rajasthan, Chengalpatti, Madurai in Tamilnadu, Unnao in U.P., Karnataka, Madhya Pradesh, Maharastra, Bihar, Delhi. There are nearly half million people in India suffering from ailment due to excess of fluoride in drinking water. In some villages of Rajasthan and Amrola in Gujarat level of the fluoride goes up to 11.0 mg/lit.[12]

Though iron content in drinking water may not affect the human system as a simple dietary overload, but in the long run prolonged accumulation of Iron in the body may result in homochromatosis, where it issues are damaged. In some districts of Assam (Barpeta, Darrang, Kamrup, Sonipni) and Orissa (Balasore, Cuttack, Puri) ground water have high iron content ranging from 1 to 10mg/l.[13]

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[12] Water Quality Issues at http://www.mowr.nic.in.
[13] Ibid pp12.

A total of 10,6019 sq. km area (about 31 percent) of Rajasthan comes under saline ground water in the state of this 88675 Sq. km area falls in western Rajasthan of Ganganagar, Barmer, Bikaner, Churu and Jaisalmer districts. The electrical conductivity of ground water in western Rajasthan is over 8ds/cm and in eastern Rajasthan over 6ds/cm. Vast low lying alluvial tract from North-Western part of Banaskantha district through the western part of Mashing and Ahmedabad districts western and north-eastern parts of Surendranagar district, Southern part of Ahmedabad and South-Western part of Kheda district is underlain by saline ground water (EC 3.46 ds/cm). Ground Water in Sangrur, Bhatinda, Ferozpur and Faridkot districts have on high as 11.30 ds/cm salinity. Groundwater is saline in almost all the canal Bhakra canal and the lift canal system of South-Western part of Haryana. About 3766 sq. km. area in Haryana is underlain by saline ground water (EC 6 ds/cm.).[14]

Arsenic in ground water have been reported in a range (0.05-3.2) mglp in shallow aquifers from 61 block in 8 districts of West Bengal namely Malda, Mushirbad, Nadia, North and South 24 Pargana, Bardharnan, Howrah and Hugli.[15]

Having understood how water can be polluted by human interaction, factors that influence the availability of water and access to it are discussed in the following paragraphs. There is a requirement to identify and focus on some of the key factors that determine whether a particular nation, or region, has water security.

Water resources management over a large terrain such as India’s vastness and complexity is, indeed, an intricate matter and it requires a multi-pronged approach involving the people at large with active support of the Government machinery.

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[14] Ibid pp14.
[15] Ibid.

The aspects that are important for water resource management are as follows:-

- Surface Runoff Management
- Watershed Linked Rainwater Management
- Locating Geomorphologic features
- Groundwater recharging
- Rainwater Harvesting
- Alternative Methods

Currently the Central Water Commission attached to the Ministry of Water Resources in the Union Government, is the organisation in India that monitors the water resources. Every drop of water should be used and re-used most judiciously both for off-farm and on-farm activities. Human interference is called for, to halt wastage and harness the surplus water to benefit the water stressed regions.

Surface Runoff Management

The surface runoff is that part of rain water and /or flood water , which gushes over the Earths natural slopes and lower order streams, and quickly transported into streams channels and then to the drainage basin of the highest order of the river in the region. The Surface runoff eventually gets emptied into the seas as surplus. Presently measures taken to harness the surface runoff are far from adequate, as a result of which the several million cubic metres of fresh rainwater goes into the Bay of Bengal as surface runoff during almost every monsoon season through perennial rivers such as Godavari and Krishna in Andhra Pradesh and Mahanadi River in Orissa.

Harnessing of surface runoff water by construction of check dams or bunds or barrier walls at locations all along the flow pattern of the water has been an age old tradition. What needs to be ensured is that these dams and bunds need to be maintained prior to the monsoons so that the holding capacity is ensured. Also as a direct outcome the ground water also gets recharged benefiting the area. If we are not able to build new tanks or reservoirs, we have to take steps to at least maintain, preserve and use the existing ones by repairing the bunds, barriers, Check dams. We also need to build new tanks and reservoirs at the foothills region and wherever there is a natural slope in the terrain, so that the runoff rainwater is most effectively managed and administered to the Indian masses.

Watershed Linked Rainwater Management

In the case of watershed linked rainwater management, the rainwater is made to saturate the parched stretches of land situated within the watershed area. Further the water that drains in the lower order streams is frequently impounded in tanks and bunded reservoirs for irrigation purpose as well as to facilitate replenishment of the groundwater resource. Watersheds should be protected from human activities because the quality of water over large areas is dependent on the cleanliness maintained in the watersheds. To arrive at the places where watersheds are required to be considered, the help from remote sensing agency using satellite imagery is the empirical means to delineate and map the watersheds in the most speedy, accurate, logical, scientific and modern means, which is verifiable by anybody , anytime and from any part of the globe. These studies can also be used to identify the prospective bunds, dams within the watersheds demarcated. Construction of multipurpose dams across high order rivers to impound water and build reservoirs might appear to be an easy way to collect surface runoff.

Seasonal Variation in Water Availability and Stress

India receives an annual rainfall of 4000 BCM which is very high to fulfill the demand for water in the country. However, only small portion of this rainfall could be put for beneficial use limiting the water availability in the country. Moreover, rainfall in the country is highly variable over time and space. Over 75 percent of the annual rainfall is received in the four rainy months of June to September only thereby leading to large variations on temporal scale. Rainfall distribution in different regions in India is depicted below:

Table 3.1

Rainfall distribution in different regions in India

	Sub-division	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE	Arunachal Pradesh				■	■	■	■	■	■			
NE	Assam and Meghalaya					■	■	■	■	■			
NE	Nagaland,Manipur, Mizoram, and Tripura					■	■	■	■	■			
E	Gangetic West Bengal						■	■	■	■	■		
E	Orissa						■	■	■	■	■		
E	Jharkhand						■	■	■	■			
E	Bihar Plains						■	■	■	■			
N	Uttar Pradesh						■	■	■	■			
N	Uttarakhand						■	■	■	■			
N	Haryana						■	■	■	■			
N	Punjab							■	■	■			
N	Himachal Pradesh							■	■	■			
N	Jammu & Kashmir		■	■	■			■	■				
N	Rajasthan						■	■	■	■			
W	Madhya Pradesh						■	■	■	■			
W	Gujarat Region						■	■	■	■			
W	Maharashtra						■	■	■	■	■		
W	Chattisgarh						■	■	■	■			
S	Andhra Pradesh						■	■	■	■	■	■	
S	Karnataka						■	■	■	■	■		
S	Kerala					■	■	■	■	■	■		
S	Tamil Nadu								■	■	■	■	■

Source: Study of Assessment of Water Foot Prints of India's Long Term Energy Scenarios, (TERI), 2017

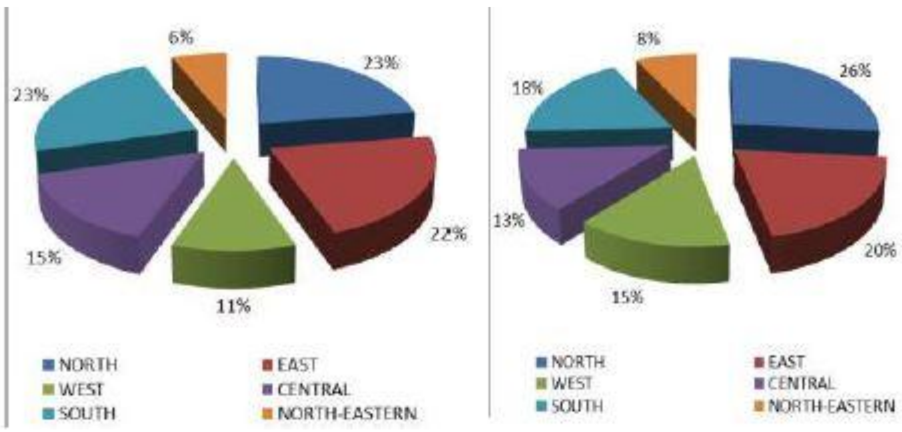
Seasonal Distribution of Surface Water Availability

In response to the seasonal distribution of rainfall, surface water availability also varies. Nationally, 85 percent of total surface water is available only during the peak season of rainfall and remaining for the major parts of the year i.e. almost 8 months of lean period. Regionally, western and central region are most deficient during the lean period with only 10 percent of annual surface water available for the period. Northern has maximum lean period surface water availability, while Haryana from northern region and Gujarat from western region are most deficient among the states. Winter precipitation in other states of northern region and eastern region supports the lean period water availability, and ranks them highest in comparison to other regions. However, uniform temporal distribution of ground water supports the total water availability in different regions. Due to its high ground water potential, northern region has highest water availability during lean period of 8 months, equivalent to about 42 percent of its annual availability. The lean period surface water and total water distribution is depicted:

Figure:3.1

Lean period surface water distribution

Lean period total water distribution



Source: Study of Assessment of Water Foot Prints of India's Long Term Energy Scenarios, (TERI), 2017

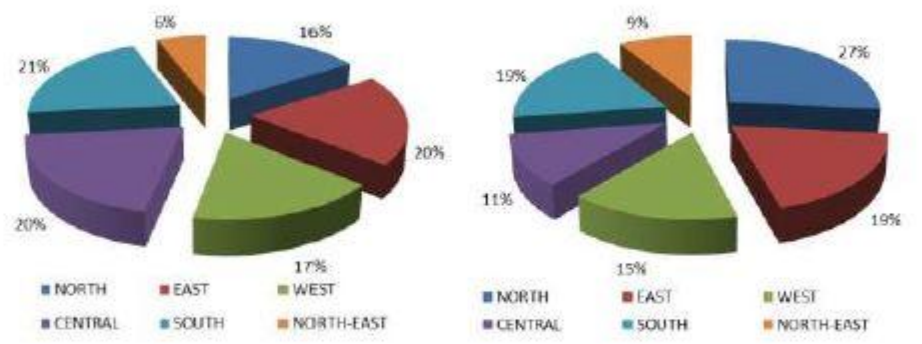
Inter-Regional Variation in Water Availability

Average water resources of the country are distributed among different river basins differently, depending on the differences in the rainfall in river catchment and their runoff patterns. Ganga-Brahmaputra-Meghna river basin is largest both in respect of their catchment area as well as average water resources potential, accounting for more than 50 percent of the total water resources in the country. However, proportion of utilizable surface water resources to average water resources potential is very high in smaller basins and is least in Brahmaputra basin. Some of the river basins with more than 50 percent of their water resources potential as utilizable are Pennar, Godavari, Krishna and Cauvery. River basins south of Indo-Gangetic plains ensure 54 percent of total utilizable surface water resources in the country. Accordingly, southern and central regions of the country have highest utilizable surface water resources, amounting to 41 percent. Due to its topography, north-eastern region while receiving maximum rainfall has least utilizable surface water resources. Similarly, northern region lying entirely within the Indo-Gangetic plains ranks second last after north-eastern region with reference to utilizable surface water resources. The region wise distribution of potentially utilizable water resources is depicted:

Figure 3.2

Region-wise distribution of Potentially Utilizable Surface Water Resources

Region-wise distribution of Potentially Utilizable Ground Water Resources



Source: Study of Assessment of Water Foot Prints of India's Long Term Energy Scenarios, (TERI), 2017

Inter-Regional Variation in Water Stress

Water stress could be defined as requirement for water as percentage of total water available. It signifies the competition for available water from water required by different sectors. As percentage between the minimum total water requirement and total water available, water stress is classified into 5 categories: Low, Medium, High, Very High and Deficit. With reference to minimum water requirement from different sectors of the economy viz., agriculture, domestic, industrial and energy, sufficient water is available in the country both nationally as well as within different regions and none of them have deficit. Sectoral water requirement in different regions as well as their water stress can be distributed as depicted:

Table 3.2

Inter Regional Water Stress

		NORTH	EAST	WEST	CENTRAL	SOUTH	NORTH-EAST	NATIONAL
		Sectoral Water Requirement (as % of total regional)						
1	Agricultural	93.9	82.5	85.4	90.3	82.3	49.3	88.1
2	Domestic	4.8	9.7	9.3	5.5	11.7	41.5	7.7
3	Industrial	0.5	5.6	2.8	1.5	3.8	3.5	2. 4
4	Energy Production	0.8	2.2	2.5	2.7	2.2	5.7	1.8
		Regional water stress categorization						
5	Annual Baseline water stress	70.1	28.9	41.2	23.2	29.3	4.8	37.1
6	Stress Category	High	Medium	Medium	Low	Medium	Low	Medium
7	Peak Season baseline water stress	68.5	23.1	28.1	1.2	27.5	2.2	28.4
8	Stress Category	High	Medium	Medium	Low	Medium	Low	Medium
9	Lean period baseline water stress	72.0	40.7	74.1	67	32.6	2.9	52.9

Source: Study of Assessment of Water Foot Prints of India's Long Term Energy Scenarios, (TERI), 2017

Throughout the country, agricultural water requirement is much higher as compared to water requirement from other sectors. Agriculture sector accounts for 88.1 percent of total water consumption in the country. Domestic sector is the 2nd largest consumer, amounting for 7.7 percent of total water consumption in the country. Water requirement for energy production is less than 2 percent of total water requirements. Individually in each region also, agricultural water requirement is higher than other sector, though their proportion varies in different regions. Agricultural water requirement in northern region is highest both in terms of actual quantity of water as well as proportion with requirement from other sectors. Lower proportion of agricultural water requirement indicates the prominence of water requirement from other sectors in the region, and is indicative of higher competitive stress between agriculture and other sectors for the available water. On an annual time scale, proportion of water requirement to water availability is between 25-50 percent, and so the country can be categorized as being under medium stress throughout the year.

Assessment of Water Stress for Future Scenarios

Increasing population and rapid economic growth is leading to increase in water demand from different sectors. Business as usual scenarios assume that the natural water availability across the river basins and so states in the country will remain constant under the given technological regimes. However, demand for water is rising continuously. Increasing population and food requirement for the people will drive both the agricultural as well as residential water demand in the country. Simultaneously, increasing urbanization and extension of irrigation facilities in agricultural cropped area will exert further pressure on continuing demand for water.

As a result, existing water stress on available water resources is increasing continuously. To quantify the changes in water stress scenarios from the current levels, an assessment of demand in response to continuing growth in different sectors was conducted. From the study carried out by TERI, the results indicate that under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) scenarios significant saving is possible in terms of volume of water consumed in agriculture sector, which could be extremely helpful in reducing water stress for other sectors like domestic and industrial.

Projections under Climate Change Scenarios

Global warming led climate change is a major challenge affecting the water availability scenarios in the country. As an additional factor to rapidly increasing population, depletion of natural habitats and resources, climate change is projected to have direct impacts on livelihoods and raising concerns for food security, water supply, health and energy. Changes in temperature pattern due to global warming have consequential impacts on precipitation patterns, both globally as well as regionally. As precipitation is the key regulator of surface water availability in any area, it gets severely affected due climate change.

According to Inter governmental Panel on Climate Change (IPCC) report in 2014, climate has shown warming of 0.89 [0.69 to 1.08] °C over the period 1901–2012 which is mainly attributed to anthropogenic activities. While climate change is supposed to have an impact on water demand also, through its influence on production of crops, evapotranspiration from crops, human water demand, increasing pollution levels in water resources etc., no reliable records are available to understand alterations in water demand patterns under future climate change scenarios. Hence, we focused future projections under climate change perspectives into variations in surface water availability and find the water stress scenarios under Business as Usual scenarios of water demand.

Changes in Water Stress under Climate Change Scenario

To understand the impacts of climate change induced variations in water availability on the water stress scenarios, increased water requirement under business as usual scenarios was compared with the modified surface water availability. Additive effects of increase in demand and simultaneous decrease in water availability have profound impact on deteriorating the water stress scenarios, over time both at the national level as well as regionally.

Similar to Business as Usual (BAU) scenarios, maximum change is water stress situation is observed for Northern and western regions. However, northern region is likely to be under 'very high stresses' condition in 2021 itself, and the intensity of stress increases by almost 5 percentage points, every decade. Similarly, current stress level of 'medium stress' in western region while intensify during the first two decades until 2031, but subsequently the region shifts to 'high stress' level. Water stress in north-eastern and eastern regions while intensifies throughout the projection period, it remains within the 'low stress' and 'medium stress' levels, respectively. But the most remarkable response is noticed for eastern and southern regions, where the water stress reduces, though minimally, under the climate change scenarios. Water stress scenario improves in these two regions in response to increase in their water availability, making them biggest beneficiary of climate change impacts in India.

Efficient Water use in Energy Demand and Supply Sectors

Water is a finite resource and as has been established in the previous chapters, all the sectors need water and they would depend on water as they grow in the future. However, water utilizable water resources are not growing at the same pace as the demand for water, and this is one of the limiting factors for expansion of energy sector. Therefore, it is imperative to efficiently use this limited yet the most important resource. Water is needed at different steps in various sectors. Some of the water conservation and efficient water use methods remain common for all the sectors, but there are some sector specific strategies that should be adopted by the sectors to become water efficient and ensure sustainable development in future of both water and energy sector. Both energy demand and supply sectors are discussed in this chapter and for some of the sectors existing best practices both at national and international level are also presented.

Energy Demand Sectors

The energy demand sectors, i.e. agriculture, domestic and industries require water for various purposes. But all the three sectors need to improve their water use efficiency. Agriculture is the most water intensive sector and it thus also provides a larger opportunity to improve water use efficiency. In domestic sector, most of the water is wasted during transmission and distribution phase with leakages as high as 30-40 percent. Also inefficient water use at household level is also one of the reasons for overall poor water efficiency in this sector. Industrial sector in India has generally 2.5-3 times more specific water consumption compared to existing international plants. Since water is a stressed resource, thus it is important to efficiently use water and minimizes its wastage. This section discusses various strategies to improve water use efficiency in each of the demand sectors with some best practices from various parts of the world.

Efficient Water use in Agriculture Sector

Agriculture is the most water intensive sector in India. More than 85 percent of water is demanded by the agriculture sector. But often it has been reported that the water use efficiency in the agriculture sector is poor and water is not efficiently used in agriculture sector. As per, Bhalage, P., et al., 2015, in India, the average water use efficiency of Irrigation Projects is assessed to be only of the order of 30-35 percent Agricultural water demand could be managed by the following strategies:

- Micro-irrigation system (MIS) including drip and sprinkler irrigation
- Bottle irrigation and Pitcher (Olla) irrigation
- Wastewater reuse

Micro Irrigation Systems

Micro irrigation methods are precision irrigation methods with very high irrigation water use efficiency (70 percent- 90 percent). It is a rational method of irrigation where in the required amount of water and nutrients are given to the root zone of the plant. It saves significant amount of water and also leads to increase in crop production. At present flood irrigation is the most prevalent form, which has low efficiency. MIS enables regulated supply of water at a required quantity and at required interval using pipe network, emitters and nozzles. Two main micro irrigation systems are Drip and Sprinkler irrigation.

- **Sprinkler Irrigation:** In sprinkler irrigation, water is delivered through a pressurized pipe network to sprinklers nozzles or jets which spray the water into the air which falls on the surface imitating rainfall. The basic components of sprinkler systems are a water source, a pump to pressurize the water, a pipe network to distribute the water throughout the field, sprinklers to spray the water over the ground, and valves to control the flow of water. The sprinklers when properly spaced give a relatively uniform application of water over the irrigated area. Sprinkler systems are usually designed to apply water at a lower rate than the soil infiltration rate so that the amount of water infiltrated at any point depends on the application rate and time of application but not the soil infiltration rate.

- **Drip Irrigation:** Also known as trickle irrigation or micro-irrigation is an irrigation method which minimizes the use of water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing and emitters. Drip irrigation minimizes conventional losses such as deep percolation, evaporation and run-off or recycled water is used for irrigation. Small diameter plastic pipes fitted with emitters or drippers at selected spacing to deliver the required quantity of water are used. Drip irrigation may also use devices called micro-spray heads, which spray water in a small area, instead of dripping emitters. These are generally used on tree and vine crops with wider root zones. Subsurface drip irrigation (SDI) uses permanently or temporarily buried dripper line or drip tape located at or below the plant roots. Pump and valves may be manually or automatically Irrigation methods operated by a controller. Emitter discharge rates for drip and subsurface irrigation are generally less than 12 litres per hour.

Wastewater Reuse

It is one of the most talked about options these days. Wastewater is considered as a resource which can be reused and agriculture is one such sector which has high potential for using treated wastewater. Most of the European countries suitably treat wastewater to a high standard which is then discharged into rivers where it gets diluted with the main flow and then re-used downstream for various purposes. Countries in North Africa and Middle East are exploring the potential of treating and reusing wastewater. In Israel, around 67 percent of wastewater is reused and mostly for irrigation and environmental purposes (FAO, 2010a). Another study (Mejia, 2010) indicates that in Mexico, around 25 percent of municipal wastewater is reused for irrigation purpose and it irrigates around 3 lakh hectares of land.

Efficient Water use in Domestic Sector

Domestic sector needs water for various purposes including drinking, washing and cleaning purpose. One of the ways to enhance water use efficiency in this sector is by managing the water demand through use of water efficient fixtures. Water-efficient appliances and fixtures can help save a significant amount of water and energy and result in long term cost saving as well. This help to conserve clean tap water and bring down costs of distribution and treatment as there is lesser volume of water to be treated and lesser wastewater generated. Significant savings can also be seen for a domestic user as well through a reduced water bill and lesser energy use, for example those who utilize booster pumps require lesser running of water. Some of the commonly used water efficient fixtures are mentioned below.

- **Faucet Aerators**: These faucet aerators add air to the water flow. This mixing of air with the flow of water results in a steadier stream. These aerators are usually simple, mesh screen made of metal or plastic with some housing that can be easily attached to the end of a faucet. As water flows through a faucet aerator it is divided into many small streams by the screens and allows the air to mix in between. This allows for the sense of high pressure with less actual water consumption. These low cost aerators can help cut down on water usage, lower utility bills, and preserve the environment. Some of these aerators have been known to save up to 55 percent of water than a standard flow.

- **Low-Flow or Sensored Faucets**: An automatic faucet or tap (also known as hands-free faucet/touch less faucet/electronic faucet/sensor faucet/motion sensing faucet /infrared faucet) is a faucet that is equipped with a proximity sensor and mechanism that opens its valve to allow water to flow in response to the presence of a hand or hands in close proximity. The faucet closes its valve again after a few seconds or when it no longer detects the presence of hands. Automatic faucets shut off automatically after hand washing resulting in reduced water waste or overflow.

- **Low-Flush Toilets and Waterless Urinals**: The Indian Standard Code of Basic Requirements for Water Supply, Drainage and Sanitation states that out of the 150 to 200 litres per head per day, 45 litres per head per day may be taken for flushing requirements. These low-flush toilets and waterless urinals can save a significant water savings. Water Free Urinal Pots which does not use water for flushing can efficiently save water. However, the major inefficiencies in this sector lie in the phase of water transmission and distribution. The leakage percentages in some cities are as high as 40 percent. Leakages and unaccounted for water must be reduced to the maximum extent possible and for that it is essential to detect leakages and losses by undertaking water audits. These leaks and losses should be controlled; water connections should be metered by installing smart meters. Some of the recommended interventions for domestic sector include:

  - ✓ Metering (both at source and end-user level)
  - ✓ Leakage control

- ✓ Well-designed tariff structures
- ✓ Pressure reduction
- ✓ Water conservation
- ✓ Reuse of water

Efficient Water use in Industrial Sector

Like domestic sector, it is also important for industries to get water audit for their plant to identify leakages and losses and then explore avenues for saving water. Industries can opt for sector specific technological improvements to improve water use efficiency within their plant premises. Besides these sector specific opportunities to reduce water use, there exist many opportunities for industrial sector to reduce water consumption, conserve water and enhance water use efficiency. Some of the interventions that industries could adopt include but not limited to:

- Reducing water footprint of the industry across its entire value chain and to enhance water use efficiency: This can be done by adopting efficient technologies which will also help increase industrial water productivity and thus will make business more sustainable.
- Recycle and reuse of wastewater: This opportunity has a huge scope and has already been implemented by many industrial units (textile industry in Tirupur).
- Institutionalize and undertake mandatory water audits & conservation measures: Water audit is an important tool to identify water losses and leakages and help in identifying avenues for water conservation. Other interventions like rain water harvesting, artificial recharge of groundwater can help to augment the scarce water resource in the region.

Setting up of standards and benchmark (e.g. minimal quantity of water used/unit of product) for water consumption and efficiency.

- Renew business strategies with financial outlay for water saving (water policy of industries)

The industrial sector can ensure efficient use of water by adopting one or more of the listed interventions and this will help industries to combat to the challenges faced by the inter-sectoral water demand and climate change impact on water resources. Other option for industrial sector is to adopt ex-situ approach in which watershed approach is adopted to conserve water beyond their premises. Through the CSR initiatives industries should undertake interventions on soil and water conservation which includes building check dams, constructing farm ponds, rainwater harvesting structures, artificial ground water recharge injection well, etc. This will help to augment the water resource of the region in which industry is located and also to adapt to the impacts of climate change. This will also help to build a better reputation with local community which are competing users for common resource in the watershed.

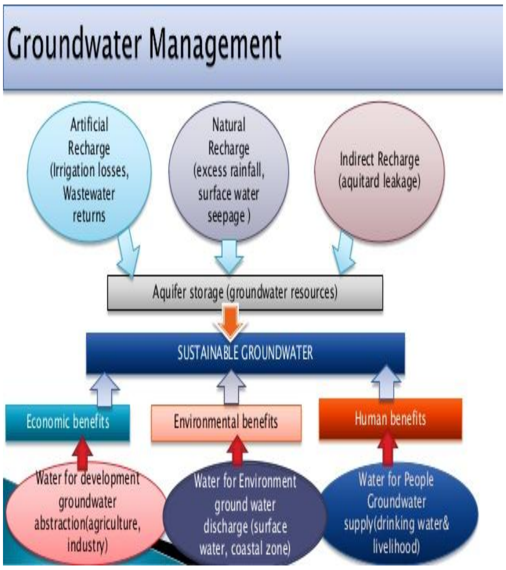
Energy Supply Sectors

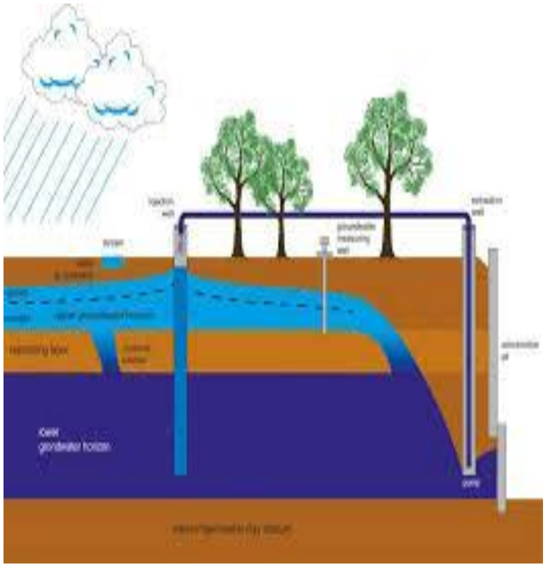
Water is also an important input in the processes of energy production by various supply sources. For various energy supply sectors, water is needed at different levels. This section discusses possible interventions to reduce water consumption for the following supply sectors:

- Fossil-based power generation. Thermal power plants are the most intensive water user in the industrial sector.
- Nuclear power stations**.** For nuclear power plants, water is required at various steps across its value chain. Water requirement starts from construction, commissioning, operation, shut-down and is needed until decommissioning phase. This section will mainly focus on effectively using water during operation phase.

- Renewable based bio-energy. Efficient water use in renewable based bio-energy. For bio-energy production, bio-crops are grown and for enhancing the water use efficiency in production of bio-crops, efficient irrigation management practices should be adopted.
- Oil & gas extraction. Water is an important input in the process of oil and gas extraction.


Irrigation System
In Ground Rain Tanks


Groundwater Management
Artificial Recharge (Irrigation losses, Wastewater returns
Natural Recharge (excess rainfall, surface water seepage)
Indirect Recharge (aquitard leakage)
Aquifer storage (groundwater resources)
SUSTAINABLE GROUNDWATER
Economic benefits
Environmental benefits
Human benefits
Water for development groundwater abstraction(agriculture, industry)
Water for Environment ground water discharge (surface water, coastal zone)
Water for People Groundwater supply(drinking water& livelihood)



CHAPTER IV

GROUND WATER MANAGEMENT

The Central Ground water board takes care of the developing and assessing the ground water potential of India. The details of the ground water potential are placed at Appendix ‘A’.[16] In addition, there are ground water departments in almost all the States. Together they carry out hydrological surveys, exploration, evaluation and monitoring of ground water regime in a continuous manner all round the year. Their role in mitigating the water crisis has been pivotal to the successful tiding over the crunchy summer months, and therefore crucial to both people as well as the governments.

With the advent of remote sensing techniques, large areas are examined for ground water potential in shorter time with more accuracy.[17] What is of essence is that the empirical field data painstakingly collected over a period of half a century has been the foundation for the exploration methods using modern techniques. What is alarming as far as ground water resource is concerned is that, out of 5711 blocks/talukas/mandals/watersheds in the country, 310 have been categorised as over exploited in other words, the stage of ground water development exceeds the annual replenish able recharge. 160 are Dark which means the stage of groundwater development is more than 85 percent. Therefore a separate Central groundwater authority was set up in the year 1997 under the Environment protection act of 1986.

The status of groundwater resource in several pockets of India, especially densely populated urban centres and semi urban places as well as intense agricultural

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Basinwise Ground Water Potential of India at http://www.mowr.nic.in.

[17] Ramasamy SM, (2005), Remote Sensing in Water Resources, Jaipur p27.

belts is extremely precarious. The whole system of groundwater has to function under a perfectly balanced mechanism of replenishment followed by exploitation. Any imbalance in this system would cause doom, and the humanity might have to pay a heavy price for creating such an imbalance. Those penalties include degradation of soil and land, creation of vast new wastelands bereft of any water resources, creation of arid zones followed in the next stage by desert type biome, incursion of seawater in coastal aquifers.

Irrigation

The first focuses on water efficiency in agriculture and includes indicators on cropping patterns as per agro-climatic zoning recommendations and the use of micro-irrigation systems. The second focuses on the problem of unchecked groundwater extraction, which is used for 63 percent of all irrigation. Given the current legal framework that assigns almost unchecked groundwater rights to landowners, groundwater extraction in India can only be controlled by through the proxy of the electricity required to operate groundwater pumps. Thus, the second segment focuses on the separation of agriculture power feeders and the pricing of electricity as the levers that states can use to control this extraction.

In recent times, there has been tremendous awareness generated among the country's masses on the importance of ground water recharging. This awareness, however, could not be so far translated to any substantial water wealth replenishments to the ground water system. Nevertheless, a large number of urban dwellers have started practicing the ground water recharging and therefore there has been a local rise in the ground water levels. Strangely rights to ground water are not clearly defined. Anyone who has a piece of land has free access to the underlying resource. Hence groundwater is treated as a common property resource. The amount of water that is legally possible to extract does not depend on the amount of land owned. Any land owner can extract any amount of water unless the geohydrology limits it. Further, the lack of well defined property rights, its invisibility and indivisibility and the complex flow characteristics makes it difficult to control or manage the use. In a socialistic society, such a legal framework is inappropriate as it does not suit the interests of all sections of the society since an individual who does not own land does not enjoy private ownership of groundwater.

The nature of groundwater problems varies from region to region and location to location and, as a result, the management solutions for one locality cannot be adopted for another. Top down legal, and regulatory approaches to control and regulate development of ground water are most likely to be less effective for the following reasons:-

- They fail to reflect the local specific problems and interests of the communities at large, and as a result could face strong opposition.
- There are many thousands of privately owned wells and most are located in rural areas, so it is difficult to monitor and catch the free riders.

Involvement of local communities in management efforts could help address these issues. Individual decisions to control pumping are not likely to create overall positive impacts on the groundwater regime as aquifers are often large with many appropriators who enjoy access to them at a time. Any saving in water due to individual actions may only result in extra pumping by neighbouring well owners. Hence there needs to be some social agreements among user groups regarding the resource water. The presence of community organisations is a pre-requisite to enable such social agreements- with the purpose of framing necessary rules and regulations and to ensure strict adherence by every member of the user community.

The role of such a community organisation is to:-

- Evolve groundwater management solutions appropriate to the locality.
- Frame rules and regulations necessary to help affect management decisions.
- Monitoring the use to ensure that individual users adhere to these rules.

To avoid any resistance from individual users from joining the community management initiatives there must be some avenues to mobilise collective action to address groundwater depletion problems by which individuals will also get direct benefits along with the larger social benefits. Also local community organisations are generally formed and operate at the village level. Aquifers are often large and their boundaries mostly do not follow the village administrative boundaries. In case of many villages are tapping the same aquifer, the decision of a village community to protect and manage their ground water may not find success unless the neighbouring communities co-operate.

Identification of the resource boundary therefore forms an important part of designing any resource management institution. In the case of groundwater there are two different ways by which resource boundaries could be demarcated. First is the boundary through which groundwater resources are replenished. The second is the boundary through which resources are being used or depleted. To effectively manage available groundwater in a locality, three aspects need focus they are, supply augmentation, induce conservation and quality maintenance.

In order to effectively regulate the use of groundwater resources, it is essential to regulate the pumping at all the points across the aquifer, irrespective of the size of the size of the aquifer which is protected or managed by the local user group organisation. Also in order to ensure effective use of available groundwater supplies, quality needs to be maintained. This means the aquifer needs to be protected from possible contamination by pollutants.

It is easier to evolve and implement water management solutions in a locality where the socio-economic profile of the communities is more or less homogenous, than in a locality where the communities are socially and economically stratified. The reason is that different groups have different water use priorities.

Having understood the various aspects of management of groundwater resource a three tier institutional structure is suggested:-

- **Institution at Watershed Level** – This is carried out at watershed level which involves more than one village. This can be called a watershed committee. All activities within the watershed will need to be co-ordinated so that it is effective. The following roles are envisaged:-
  - ✓ Setting up village level institutions.
  - ✓ Co-ordinate activities.
  - ✓ Resolving conflict between villages.
- **Institution at Aquifer Level.** This is at the aquifer level which will necessarily regulate the quantity of water that is withdrawn. The roles envisaged are:-
  - ✓ Amount of water that can be drawn
  - ✓ Recharge estimates
  - ✓ Demarcation of water sheds
  - ✓ Suggest suitable crop patterns
  - ✓ Suggest efficient irrigation techniques

- **Village level institutions**

Community participation in the management of groundwater resources is a totally new area and experience is lacking. Conflicts are likely to emerge as communities start managing their local resources. Suitable legal and policy framework is required to be created by the government which should also include defining a new water rights structure and setting up a technical service cells for local community organisations. There are 575,000 villages in India. People in these villages are poor due to underemployment. This results in various conflicts. If the water resources in the villages are properly managed, it would enable the villagers to grow multiple crops. This will generate gainful employment. The role of Panchayat Raj Institutions in management of water resources would greatly help to prevent conflicts in villages.

Ground Water Management Techniques

Certain foreign countries and states in the India have adopted positive measures to rejuvenate and recharge ground water resources. Some of the case studies are discussed below:

Israel

Despite being one of the most water scarce countries in the world, Israel has achieved water security and full cost recovery through tariffs through a series of ambitious reforms. This involved nine key innovations, namely:

- Putting in place a national water conveyance system to connect all water infrastructure,
- Reuse of treated wastewater for irrigation,
- Large-scale desalination PPP for potable water independence,

- Using aquifers as reservoirs,
- Interception of surface water run-off,
- Promoting crop selectivity and importation of virtual water,
- Efficient irrigation technologies,
- Demand management and public communication, and
- Creating a supporting environment for innovation.

The Israeli experience holds nine important lessons learned, which are of major importance for other countries facing increasing water scarcity:

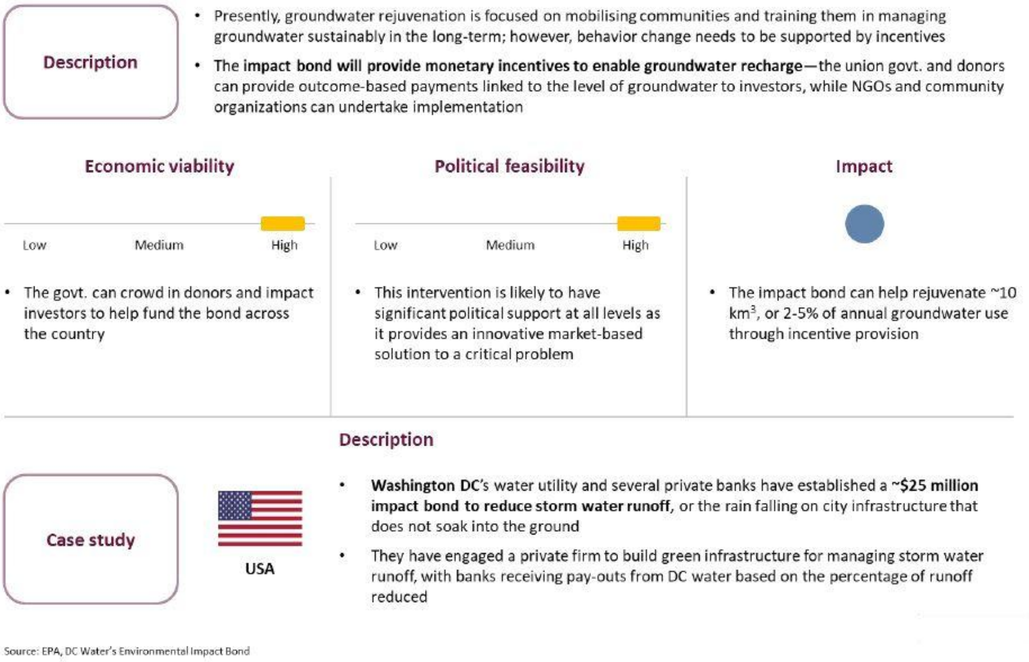
- Building public awareness of the value of water,
- Control of water allocations,
- Access to quality data for integrated management,
- National conveyance water system,
- Massive infrastructure investment in parallel with institutional reforms,
- Low price for desalinated water depends on well-designed PPP schemes,
- Wastewater reuse is beneficial but requires subsidies,
- Corporatization of water utilities requires sound regulation and heavy-handed supervision, and
- Even in a country with large resources and strong capacity, this has been a long process and mistakes have been made.

To improve the performance of ground water restoration it is important to explore incentive-based mechanisms such as an innovative water impact bond that pays out funds to community organizations/ NGOs on achieving groundwater recharge targets. A case study of USA in this regard is depicted[18]:

[18] Composite Water Management Index by NITI Aayog, June 2018

Figure 4.1

Developing an Impact bond for ground water rejuvenation



Source: Composite Water Management Index by NITI Aayog, June 2018

Meghalaya

Recent developments, such as the water shortage in the city of Cherrapunji, the second wettest place in the world in terms on annual rainfall in 2015, have brought water management onto the agenda of the state government. Apart from the improvement in rural supply, the state is pushing to get 65 new minor irrigation projects approved, which are expected to increase its command area by~20 percent. Further, WUAs have been established in several irrigation projects, small reservoirs are being created to store water, and a water act is being formulated. These positive steps indicate that the water management has climbed up in the state's policy agenda and bode well for the state's future performance on the Index.

Central Sector

Madhya Pradesh and Rajasthan have benefited from community galvanization, led by local officers and NGOs, for the restoration of traditional water bodies such as farm ponds and tanks. Since 2006, farmers in the Dewas district of Madhya Pradesh have constructed 8000 ponds, thereby creating an irrigation potential of 40,000 hectares. These have been enabled by loans obtained through banks, such as NABARD, with the help of NGOs and government officers.

Andhra Pradesh

A successful model of a potentially replicable groundwater intervention comes from Andhra Pradesh and its Farmer Managed Groundwater Systems (APFMGS) scheme that targets the key problem related to groundwater—unchecked extraction by farmers. The intervention conducted with the help of the Food and Agriculture Organization (FAO), educated farmers about the best practices surrounding groundwater use through workshops and provided equipment to measure groundwater and rainfall data. From 2005 - 07 the intervention was able to save 10 million m^3 of water[19]. In addition to farmer advisory, market based interventions such as an impact bond for groundwater (highlighted earlier in the thematic section) can be used to incentivize community organizations and entrepreneurs to innovate for groundwater recharge.

[19] BIRDS. (n.d.). Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) Project: Demand Side Management of Groundwater.(2016) Annual report, website: http://www.birdsorg.net/

Sikkim: Dhara Vikas

Dhara Vikas is an innovative programme to revive and maintain drying springs in the north-eastern state of Sikkim. A robust climate adaptation strategy for drought-prone districts, Dhara Vikas (meaning, spring-shed development) is helping to alleviate the problem of rural water scarcity by reducing surface runoff of rainwater and allowing more water to percolate down to recharge underground aquifers, which, in turn, ensures increased discharge from springs. Besides its significant impact on crop patterns and yields, the programme has also worked on developing a village spring atlas and a water source atlas for the state. Water access to the population through this initiative has also led to improved sanitation practices. Recognising the urgent need for ensuring water security, the Rural Management and Development Department (RMDD), Government of Sikkim (GoS), conceptualised the Dhara Vikas initiative to revive the state's dying lakes, springs and streams. Estimates suggest that in mountainous terrain less than 15percent rainwater percolates down to recharge springs, while the rest is lost as surface water. The core thrust of Dhara Vikas is to catch this runoff water and use it to recharge groundwater sources. The primary objective of Dhara Vikas is to ensure water security by breaking the cycle of abundance and scarcity of water. It also seeks to enhance the hydrological contribution of the mountainous ecosystem as a water tower for the people, and ensure disaster risk management by reducing landslides and floods. This initiative is being run by various departments of government with the support of private institutions. RMDD is the nodal agency for this initiative.

Nodal Agency

- Department of Rural Management and Development

Government Departments

- Department of Forest, Environment and Wildlife Management
- Department of Science and Technology and Climate Change
- Department of Mines and Geology
- Indian Space Research Organisation, Department of Space, Bengaluru

Private Institutes

- G.B Pant Institute of Himalayan Environment and Development
- World Wildlife Fund (India)
- Gesellschaft für Internationale Zusammenarbeit (India)
- Peoples' Science Institute, Dehradun
- Chirag, Nainital
- Arghyam, Bengaluru
- Advanced Centre for Water Resources Development and Management (ACWADAM), Pune
- Tolani Maritime Institute (TMI) India, Sikkim
- Bhabha Atomic Research Centre, Mumbai

Beneficiaries

- People of South and West districts in Sikkim

Dhara Vikas aims to revive and maintain the dhara (springs) in the South and West districts of Sikkim by using rainwater harvesting, geohydrology and Geographical Information System (GIS) techniques. Simultaneously, RMDD identified the recharge areas of various springs and streams based on the varying structure, weathering and fracture pattern of rocks. The pilot phase in the year 2010 aimed at reviving the Nagi Lake in South Sikkim district, focussed on digging of trenches and laying of pipes for the recharge of select lakes and springs. The encouraging results of these interventions became evident by 2011, after which the initiative was scaled up in 2012 to cover the South Sikkim and West Sikkim districts. Dhara Vikas enabled a remarkable convergence of expertise from various departments like forest, mines and science and technology, who provided their specialised knowledge on relevant subjects. Activities such as laying of trenches and GI pipes were taken up under the national flagship MGNREGA programme. The initiative's strategic focus has been on controlling runoff water and increasing its permeation to enhance groundwater recharge.

Activities toward this objective include developing springs-sheds, enhancing hydrological contribution of hill-top forests, reviving lakes to function as recharge structures, expanding minor irrigation networks for paddy cultivation, terracing sloping lands, enhancing water storage infrastructure, developing para-professionals in geo hydrology, and carrying out research and documentation. Dhara Vikas has not required any separate grievance redressal mechanisms. The nature of initiative has been such that it required the committed involvement of villagers, as the problem being addressed impacted all the members of the community. Decisions related to digging of trenches and recharge points were based on principles of geo hydrology, which mitigated the potential problems associated with arbitrary decisions. All work related resolutions have been taken up in the Panchayats and sorted through village-level discussions.

Activities Initiated by the Dhara Vikas Programme

Developing a cadre of in-house trained para-hydro-goelogists in coordination with NGO partners. Simultaneously, climate change related vulnerability assessment of the villages was conducted. Resource mapping and preparation of village spring atlas conducted. In the process, recharge areas of various springs and streams were identified based on local geohydrology. Laying of contour trenches and preparing for rainwater harvesting of various lakes and springs. According to RMDD, the success of the programme, which has revived five lakes and 50 springs, has generated more demand from villages that suffer from similar water scarcity. With the revival of lakes and springs and the increased awareness, villagers in the area have also started constructing water storage tanks. They use the day-time discharge from springs for irrigation, while the night-time discharge is used to fill personal tanks by rotation.

Pilot Project - Nagi Lake

Before the launch of the Dhara Vikas programme, the Nagi Lake in South district of Sikkim had dried up, gradually killing all the springs recharged by it. The pilot project made the lake perennial again and resurrected springs, such as Setikhola, thereby providing water security even during dry months.

Key Challenges

As this initiative involved the implementation of a new concept, many lessons were learnt along the way. Trenches for groundwater recharge were initially dug without adherence to geo-hydrological requirements. Some trenches were dug on terraced fields instead of on sloping land, while others were dug without supervision which could ensure maximum trapping of surface runoff, thus making them ineffective. Similarly, many horticulture and forestry activities initially undertaken to improve groundwater recharging did not show any positive outcomes. In time it was realised that trenches and ponds had a greater impact on groundwater recharging and soil moisture than plantations, which lose moisture through evaporation. In certain locations, the lean period discharge was not recorded, making any conclusive impact assessment impossible. Also, as the programme gathered momentum, its positive effects generated demand for scaling up, which could not be met due to the limited number of trained staff.

Dhara Vikas' Innovative Approach

- Developed para-geo hydrologists to bridge the knowledge gap on geo-hydrology and revival of springs at the village level
- Adopted a landscape-level approach by reviving springs, streams and lakes
- Succeeded as a community-driven initiative that created grassroots demand by successfully carrying out pilot projects on spring-shed development
- Linked with the MGNREGA national scheme for sustainable funding support.

Replicability and Sustainability

The ecologically sound and scientific solution implemented by Dhara Vikas is seen as a highly replicable strategy to tackle the pervasive and persistent problem of water scarcity in mountainous regions. Representatives from countries like Nepal and Bhutan, which have a similar topography as Sikkim, as well as from other hilly Indian states, like Arunachal Pradesh and Himachal Pradesh, have visited the state to understand the process of spring-shed development. They plan to implement similar initiatives in their respective geographies. The sustainability potential of this initiative is also reasonably high, as it taps into plan funds and the MGNREGA scheme and uses infrastructure that already exists within various Departments. Other than the trenches and GI pipes used for groundwater recharging, Dhara Vikas does not demand the creation of any new infrastructure. Once the initial pilot is successful, the impact itself paves the way for Gram Panchayats taking up ownership as well as the responsibility for upkeep and maintenance of the project.

Lessons Learnt

Dhara Vikas has had a profound impact on the lives of people living in water-scarce areas of Sikkim, and this innovative intervention is set to continue in future. In keeping with its utilisation of latest technology for spring-shed development, Dhara Vikas has initiated an environmental isotopic fingerprinting study of springs in Sikkim, in collaboration with the Bhabha Atomic Research Centre (BARC), to increase knowledge of mountain aquifers. This technique can further strengthen the understanding of recharge areas and pinpoint specific locations for optimal recharge of a spring. Apart from this, a training handbook is being prepared to illustrate the process of groundwater recharge. Pilots of other water security initiatives, including documentation of village water budget, village recharge areas and ways in which water efficiency can be enhanced are underway.

Lake Restoration

A large number of lakes in urban India are threatened and in dire need of conservation and restoration. The 300-acre Mansagar lake in Jaipur and the 48-acre Kaikondrahalli lake in Bengaluru, were among such lakes that were plagued by a host of issues. The biggest threat these two lakes faced came from pollution, which destroyed the ecology of these lakes, contaminated the surrounding groundwater and caused a foul odour. The impetus for the lake's restoration came with the recognition of its huge potential for tourism. Both the lake and the historic Jal Mahal Palace, which is situated at the centre of the lake, were in a state of decay and needed to be restored to their former pristine condition. The restoration strategy involved leasing out the lake and linking its health to revenues from tourism.

Kerala : Mazhapolima

It's a participatory climate change adaptation initiative which was launched by the Government of Kerala in Thrissur district in 2008. The project aims to alleviate the problem of water scarcity by harvesting rainwater from rooftops and feeding it into open dug wells, which traditionally form the water security mechanisms of the state. Active participation of Gram Panchayats, private agencies and beneficiaries led to the installation of over 10,300 Mazhapolima units with government subsidy. The effect of these units on groundwater levels has encouraged more than 10,000 households to adopt Mazhapolima open well recharging systems at their own cost.

Seeking to tackle the acute water scarcity, the District Collectorate of Thrissur launched Mazhapolima (meaning, bountiful rainfall) in 2008 as a climate change adaptation initiative to augment groundwater resources through rainwater harvesting. Under this model, rainwater from rooftops is collected and filtered before being routed down to recharge open dug wells. This also leads to the formation of a fresh water zone at the source of the dug wells. Active participation of Gram Panchayats, private agencies and beneficiaries led to the installation of over 10,300 Mazhapolima units with government subsidy. The effect of these units on groundwater levels has encouraged more than 10,000 households to adopt Mazhapolima open well recharging systems at their own cost. initiative took into account the region's unique geohydrological factors: the area receives average annual rainfall of 3,000 mm; open dug wells form unconfined aquifers; there are 200 homestead open dug wells per sq km; the water table goes down in the summer when 75 percent of the 4.5 lakh wells dry up; and the coastal belt suffers from saline intrusion.

Objectives

Mazhapolima was initiated to enhance the water table and increase water availability in open dug wells throughout the year; improve the quality of water in open dug wells; reduce public spending on water tankers, and reduce saline intrusion into open dug wells along the coastal line.

Stakeholders

- Households, institutions with wells facing water scarcity
- District Collectorate, Thrissur (Provided administrative support)
- District Rainwater Harvesting Mission-Mazhapolima (Nodal Implementing Agency)
- Revenue Department, Government of Kerela, (Financial Assistance)
- Arghyam, Bengaluru (Financial Support)
- Panchayati Raj Institutions
- Departments of Education, Sanitation, Planning, Rural Development (Facilitating roles)
- State Bank of Travancore
- Thrissur Pooram City Chamber (young mens’ club)
- Malyalam Manorama (Media)

Mazhapolima has clearly demonstrated the ability to respond to a common need with a simple but effective solution that covers four key components – innovation, awareness generation, grievance redressal and trainings.

Innovation

The concept of rainwater harvesting is not new. However, the participatory model of implementation under Mazhapolima and the convergence of the efforts of various agencies and actors are innovative. The major innovative strands under this initiative include its PRI centric, participatory approach to rainwater harvesting; creation of a dedicated unit at the district level to assist GPs in technical implementation; extension of the initiative to various government and private institutions; convergence of existing government schemes such as Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) scheme, Integrated Watershed Management Programme (IWMP), and Western Ghat Development Programme; and encouragement of private investment in cash or kind to ensure ownership of the initiative by the beneficiary. Government assistance is provided only to Scheduled Caste (SC), Scheduled Tribe (ST) and BPL beneficiaries.

Towards Awareness generation one innovative case is discussed: The drought of 2004 was the immediate trigger that escalated the issue of water conservation and management to the top of the public agenda. While efforts were being made by the district management to meet this crisis, the vernacular media, especially Malayalam Manorama, launched a dedicated campaign on the issue of water conservation called Pala Thulli (many drops) in Thrissur district, which propagated various means of achieving a new water culture. For more than a year, the newspaper dedicated a page to the Pala Thulli campaign, organised seminars and workshops, held exhibitions and video shows, and distributed booklets. These efforts were especially targeted at the youth, and created an unprecedented awareness on the subject. The newspaper also announced a Pala Thulli Award for outstanding work by institutions in water conservation.

Techniques used in Mazhapolima

Mazhapolima units adopted two types of techniques. One technique is roof-top harvesting with sand filter, where PVC gutters are fixed to collect roof-top water, which is then diverted to the filter using a PVC pipe. The filter consists of sand, metal and charcoal. This technique costs Rs. 2,500-3,750 per unit. The second technique is roof-top harvesting with ordinary nylon filter, through which the roof-top water is harvested and diverted to the well through a nylon or cloth filter using a PVC pipe. This option reduces the cost to Rs. 1,250-2,500 per unit.

Lessons Learnt

Mazhapolima has importance in the light of the drastic and dramatic global climate change scenario. One of the sustainable ways to deal with the threat is to embrace adaptation mechanisms that reverse or at least limit the adverse impact of climate change. Such initiatives are the need of the hour, even if the pace of change and adoption is slow initially. Seeing Mazhapolima's success, the Government of Kerala has recently sanctioned 2 crore to further strengthen the rainwater recharge programme. Of this, 1 crore is used to construct 20 check dams in the drought prone blocks so that the harvested water can percolate down to recharge open wells in lower regions. The remaining amount is sanctioned to 59 local self-governments to implement the Mazhapolima programme. The beginning of a new water culture in Kerala has indeed been made.

Observations on Water Management Techniques in India

Almost none of the states have built the infrastructure required to recharge groundwater in overexploited and critical units, thereby highlighting a key constraint in the recharging process. The key driver of India's groundwater crisis is the current legal framework (riparian law) that ties land rights to water rights and allows landowners to extract groundwater unchecked. Since groundwater is a common, finite resource, this has implications for both the distribution and sustainability of groundwater in the country.

Currently, ~55 percent of the reporting states (12 out of 22) have put in place a regulatory framework for managing groundwater. However, worryingly, several of the populous northern states, including UP, Bihar, Rajasthan, etc., have not drafted any such regulation. Given that these states produce ~20-30 percent of India's agricultural output, and that groundwater accounts for 63 percent of all irrigation water[20], unsustainable extraction in these states poses a significant food security risk for the country going forward. At the national level, the Ministry of Water Resources (MOWR) has drafted a model Groundwater Bill that specifies a legal and regulatory framework for groundwater, with the eventual objective of having all the states adopt the bill with the requisite modifications[21]. Currently, the Bill has been sent out to the states for discussion.

Most states have lined about half of their identified canal and distribution network lengths, with signs of improvement year-on-year. The median state has lined ~52 percent of suitable canal length in FY 16-17. Gujarat, Haryana, Karnataka, and Madhya Pradesh are some of the larger states performing well, while other states with large irrigation assets, such as Maharashtra, UP, and Bihar, are still lagging behind. North-Eastern and Himalayan states, for which data is available, have performed as well as the Non- Himalayan states, with Himachal, Uttarakhand, and Tripura being in the top 10 nationally. There has been a modest improvement in achievement from the base year (FY 15-16) with 12 states improving their scores—Madhya Pradesh is the

[20] Planning Commission Data book 2014; India Energy Statistics 2015; FAO AQUASTAT database
[21] MOWR website

only significant gainer with a 75 percent increase on base year achievement. Further improvements in irrigation distribution efficiency using advanced technology are also being explored by states. Pushing ahead with the modernization of distribution networks, the Karnataka government has established a SCADA (Supervisory Control and Data Acquisition) system, including GIS technology, in a canal on the Krishna river to monitor and control water flows in real time, and provide this information to farmers through an online dashboard. Several countries, such as Israel and Singapore, already use sensors and analytics software to improve water distribution efficiency and Indian states can partner with these countries to enable the technology transfer process.

Most states in India, including those with a large no. of irrigation projects, remain highly dependent on rain-fed agriculture. The median state in the Index has ~60 percent of its agricultural area as rain-fed. Even states with more than 100 MMI projects, including Maharashtra, Rajasthan, Jharkhand, and Karnataka, have 80- 90 percent of rain-dependent cultivated areas. On the other hand, the large agricultural states of Punjab and UP have been modernizing their farms for years and have ~90 percent of land under irrigation. Across the North-Eastern and Himalayan states, there is wide variation in rainfall dependency, ranging from 86 percent in Sikkim to 31 percent in Uttarakhand. 52 percent of India's agricultural area remains dependent on rainfall; the future expansion of irrigation needs to be focused on last-mile efficiency.

Given the fact that even the states with the highest number of irrigation projects remain highly dependent on rainfall, the design of new irrigation systems needs to be focused on optimizing last-mile reach and efficiency. This can involve the inclusion of monitoring technology, early inclusion of relevant stakeholders in irrigation plans, and embedded linkages to on-farm technologies such as micro-irrigation. In fact, it is vital to ensure that water-saving technologies form the bedrock of irrigation expansion plans to ensure that fresh and groundwater resources are not strained further with the modernization of the country's agriculture. The government, thus, needs to position micro-irrigation and farmer advisory at the center of its irrigation expansion schemes and provide appropriate linkages and incentives for adoption.

A majority of states in the country have made significant progress towards their targets for constructing and rejuvenating water harvesting structures for watershed development. Five states—Andhra Pradesh, Punjab, Tamil Nadu, Goa, and Himachal Pradesh have constructed 100 percent of their target structures in FY 16-17. Overall performance is also high, with the median state achieving ~78 percent of its targets. At the category level, Non-Himalayan states have performed better than North-Eastern and Himalayan states, achieving an average success rate of ~73 percent as compared to ~58 percent for North-Eastern and Himalayan states. The largest beneficiaries of the watershed programmes have been small farmers, local communities, and rural workers. The programmes have helped build local water infrastructure, such as ponds, check dams, tanks,etc., leading to an increase in irrigation potential for small farmers and a reduction in water variability for local communities. These watershed programmes are also creating lakhs of jobs, with water and soil conservation projects being responsible for 80 percent of all MGNREGA work[22]. Several states, such as Kerala, have included local communities throughout the watershed development process, from planning to implementation and monitoring, to ensure sustainability of the structures. Low performing states can boost

[22] www.nrega.nic.in

achievement by similarly involving local communities to achieve buy-in and fast-track the construction process.

Overall performance on geo-tagging water conservation assets is robust even large states with a massive number of projects have geo-tagged a majority of them and has improved significantly in the last two years. In FY 16-17, the median state had geo-tagged ~72 percent of its IWMP assets. Further, even states with more than 50,000 assets, such as Gujarat, Andhra Pradesh, Rajasthan, Tamil Nadu, and Maharashtra, had almost completed a massive undertaking, having geo-tagged more than 75 percent of their assets. A majority of this progress was made in FY 16-17, with the median state's achievement increasing from ~37 percent in the base year (FY 15-16) to the aforementioned ~72 percent. In terms of absolute achievement, Rajasthan improved the most between the years, managing to geo-tag a staggering ~55,000 assets in a single year. This policy is a positive step towards a data-rich ecosystem for water that can enable policy targeting and innovation. The mandatory geo-tagging of water conservation assets, combined with satellite remote sensing data, not only enables real time progress monitoring, but can also be integrated into state, and potentially national, water data platforms/ centers. The integration would allow precise measurement and identification of successful intervention typologies for recharging groundwater, restoring surface water bodies, etc.

Most states in India have instituted a legal framework for involving WUAs in participatory irrigation management. ~80 percent of reporting states (19 out of 23) have established a framework for involving WUAs. Punjab, among the Non-Himalayan states, and Meghalaya, Uttarakhand, and Tripura, among the North-Eastern and Himalayan states, are the only ones to not have instituted such a framework, while there is no data available for Haryana. There is a lot of variation in the involvement of Water User Associations (WUAs) in irrigation O&M across states, and states with the largest irrigation areas have worryingly low participation. The median state in FY 16-17 had WUAs involved in the O&M of ~21 percent of irrigated area, with participation rates for high performers clustered around ~70 percent, while low performers have sub-20 percent rates. Gujarat and Uttar Pradesh, the states with largest areas under irrigation, also belong to the low performing category, implying that a significant proportion of the country's irrigation area does not have WUA involvement. North-Eastern and Himalayan states perform even more poorly, with most having no WUA involvement at all.

Rajasthan has been a pioneer in involving WUAs to better manage irrigation in the water-scarce state. Rajasthan has achieved high levels of WUA participation due to the early establishment of a regulatory framework to involve farmers in irrigation management (The Rajasthan Farmer's Participation in Management of Irrigation Systems Act, 2000) and the inclusion of WUAs as a major component in the planning and implementation of large water projects, including the water restructuring project with the World Bank in the mid-2000s and the upcoming $100 million rehabilitation of the Indira Gandhi Canal.

Overall, states have displayed excellent performance, with ~80 percent of reporting states having more than 75 percent of area planted as per agro-climatic zoning. 19 out of 20 Non-Himalayan states have figures above 75 percent, a hugely encouraging fact, given that these states contain the majority of cultivated area in the country. Tripura and Sikkim are the high performers among the North-Eastern and Himalayan states, but Assam, worryingly given its position as the largest state in this group, has almost no area planted according to agro-climatic zoning. Further, data is not available for Punjab and Haryana, which have some of the highest cultivated areas in the country. Given the fact that agriculture utilizes 90 percent of the country's annual water consumption, planting crops in a water-efficient manner is a key lever for overall sustainability, and the exceptional performance of states in this indicator bodes well for the future. Despite excellent overall performance, inconsistencies exist within states, with water-intensive sugarcane being grown in the drought-prone areas of Maharashtra being a well-documented example. These problems can be corrected by building in water considerations into the decision processes for agricultural incentives such as MSPs and fertilizer subsidies.

Pricing of Electricity to Tube Wells/ Water Pumps

Whether states are charging farmers for the electricity provided to tube/ bore wells that are used to extract groundwater for irrigation. It consists of three binary sub-parts: the first indicates whether a state is charging for the electricity at all, while the second and third parts check whether the charges are fixed (such as a fixed amount per month regardless of units used) or metered (implying a charge per unit used) respectively. This is a critical indicator as groundwater currently accounts for 63 percent of all irrigation water. In fact, the unchecked extraction of groundwater by farmers is driving the country's groundwater crisis, with 54 percent of wells declining in levels due to extraction rates exceeding recharge rates[23]. This unchecked extraction is largely driven by two policies. First, the current legal framework for groundwater allows farmers to extract water unchecked from underneath their land. Second, low electricity prices for farmers to boost irrigation have created an unsustainable situation. Given this worsening crisis, states are slowly moving towards charging farmers for electricity.

[23] FAO AQUASTAT database; WRI

Under-and non-pricing of electricity to farmers remains one of the biggest water problems in the country. Independent surveys[24] show that even now, most connections for farmers in the rural areas of large northern states are not metered, and inevitably, in the vast majority of metered connections, the true cost of providing electricity is highly subsidized. These policies lead to over-extraction of groundwater for use in inefficient irrigation practices such as flood irrigation, and thus, exacerbate the zero-sum nature of groundwater extraction for irrigation—large farmers are able to buy more pumps and extract large amounts, reducing the irrigation potential for smaller farmers. A gradual movement towards true-cost pricing of electricity for tube/ bore wells to encourage efficient cropping and irrigation practices is, thus, one of the key levers for solving India's groundwater crisis.

State performance on installing micro-irrigation systems is extremely poor across the board, with no state having these systems in more than roughly one-third of the irrigated area. The median state in FY 16-17 had installed micro-irrigation systems on only ~2 percent of irrigated area, with the average across states being ~10 percent. Most worryingly, several large agricultural states, such as Punjab, Uttar Pradesh, Haryana, and Tamil Nadu, have negligible micro-irrigation adoption. Even the leading states—Gujarat, Karnataka, Maharashtra, and Andhra Pradesh—have systems in only ~20-35 percent of irrigated area. Among the North- Eastern and Himalayan states, Tripura and Sikkim are the only ones with more than 10 percent coverage, while the largest state, Assam, has negligible coverage.

These numbers highlight one of the major causes underlying the inefficient use of water by Indian farmers, who currently have one of the lowest water efficiencies in the world, using 3-5X of water for producing the same amount of crops

[24] Survey conducted by Dalberg and Sambodhi Research across Tamil Nadu, Rajasthan, UP, and Bihar for a previous engagement

as compared to farmers in China, the US, and Israel. It is critical to accelerate micro-irrigation adoption to improve water-efficiency in the largest water-using sector of the country. With agriculture using 90 percent of the country's water, widespread micro-irrigation can make a major dent in the projected water deficit for the country. As an example, Israel, one of the most naturally water-scarce nations in the world, has managed to transform itself into the leading global water manager by building on the efficiency gains unlocked by micro-irrigation systems (which it invented). To achieve this transformation, the government needs to accelerate the process of providing Direct Benefit Transfers (DBT) for micro-irrigation subsidies (which it has already announced) to enable innovation and consumer choice in the micro-irrigation market. The government already has a successful programme to draw from, having pushed through DBT subsidies for LPG recently.

Data and centre-state and inter-state cooperation are some of the key levers that can help address the crisis. Data systems related to water in the country are limited in their coverage, robustness, and efficiency. First, data is often not available at the adequate level of detail. For example, water use data for domestic and industrial sectors is available at only the aggregate level, and thus provides very little information to relevant policymakers and suppliers. Second, where data is available, it is often unreliable due to the use of outdated collection techniques and methodologies. For example, groundwater data in India is based on an inadequate sample of ~55,000 wells out of a total ~12 million[25] in the country. Finally, siloed information collection and sharing, especially between states, adds significantly to costs and inefficiencies. There is also an opportunity to improve centre-state and inter-state cooperation across the broader water ecosystem. Water management is often currently viewed as a zero-

[25] Fifth MI Census. India

sum game by states due to limited frameworks for inter-state and national management. This has resulted in seven major disputes regarding the country's rivers, involving 11 states, as well as limited policy coordination on issues like agricultural incentives, pump electricity pricing, etc. These issues can be addressed by boosting cooperation at a federal and inter-state level.

The Water Index scores for FY 16-17 vary from 76 (Gujarat) to 26 (Meghalaya), with the median score being ~49 for Non-Himalayan states and ~31 for North-Eastern and Himalayan states. Gujarat is the highest performer, closely followed by other High performers such as Madhya Pradesh and Andhra Pradesh. Seven states have scores between ~50-65 (including two North-Eastern and Himalayan states) and have been classified as Medium performers. Alarmingly, ~60 percent of states (14 out of 24) have achieved scores below 50 and have been classified as Low performers**.** Low performers are concentrated across the populous agricultural belts of North and East India, and among the North-Eastern and Himalayan states.

Significant improvements are required in states' performance across critical indicator themes. The performance of states has varied widely at the level of the nine indicator themes. Most of the states have done well in the infrastructure-heavy themes of 'Major and medium irrigation' and 'Watershed development' and have also enacted policies corresponding to the recommendations within the 'Policy and governance' theme. However, the critical themes of 'Source augmentation (Groundwater), 'Sustainable on-farm water use practices', and 'Rural drinking water' are lagging behind.

Most states have achieved less than 50percent of the total score in the augmentation of groundwater resources, highlighting the growing national crisis

54 percent of India's groundwater wells are declining, and 21 major cities are expected to run out of groundwater as soon as 2020, affecting ~100 million people[26]. Further, 70 percent of states have also achieved scores of less than 50 percent on managing on-farm water effectively. Given the fact that agriculture accounts for 80 percent of all water use[27], this underperformance, as discussed in the analysis of low performers above, poses significant water and food security risks for the country. Finally, states have also performed averagely on providing safe drinking water to rural areas. With 800 million people, or ~70 percent of the country's population, living in rural areas, and about two lakh people in the country dying each year due to a lack of access to safe water, this is one of the most critical service delivery challenges in the world.

Best estimates indicate that India's water demand will exceed supply by a factor of two by 2030, with severe water scarcity on the horizon for hundreds of millions. One of the key challenge levers driving this crisis is the lack of water data. Data systems related to water in the country are limited in their coverage, robustness, and efficiency. The sector suffers from the following key data problems[28]:

- **Limited coverage***:* Detailed data is not available for several critical sectors such as for domestic and industrial use, for which data is only available at the aggregate level and lacks the level of detail required to inform policies and allocations.
- **Unreliable data***:* The data that is available can often be of inferior quality, inconsistent, and unreliable due to the use of outdated methodologies in data collection. For example, estimates on groundwater are mostly based on

[26] Composite Water Management Index by NITI Aayog, June 2018
[27] WRI; World Bank (Hindustan Times, The Hindu)
[28] CWC; CGWB; CPCB, Composite Water resource Management, NITI Aayog, June2018

observation data from 55,000 wells, while there are 12 million wells[29] in the country.

. **Limited coordination and sharing***:* Data in the water sectors exists in silos, with very little inter-state or centre-state sharing, thereby reducing efficiencies. Such data issues directly impact policy formulation, increase problems in infrastructure maintenance, promote sub-optimal user behaviour, and limit research and innovation.

Despite the worsening water crisis in the country and significant challenges, there is room for optimism, with water management receiving increased policy attention over the past few years. From 2014 onwards, the Indian government has taken several steps to move the country further along the path to effective water governance, with the key policy decisions detailed in the timeline below. Some of the key policy highlights include:

- **Basin-level Governance***:* The consolidation of several river authorities into the central Ministry of Water Resources, to enable better decision-making for surface water projects and allocation.

- **Groundwater Bill:** The drafting and discussion of a model groundwater bill that defines groundwater as being held 'in trust' by the government and specifies a decentralized structure for its governance.

- **Innovative Irrigation***:* The renewed focus on micro-irrigation adoption by farmers in the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) to enable efficient on-farm water use.

[29] Fifth MI Census, India

- **Global Partnerships***:* The formalization of a partnership with Israel, the world leader in water governance and conservation, to leverage Israeli experience and knowledge for water conservation in India.

Further, global events and examples have highlighted both the potential implications of water scarcity and the pathways to achieve water security. The worsening water crisis in Cape Town, South Africa, with the city hovering dangerously close to 'Day Zero' (when it runs out of water), has caused water rationing and civil strife in the city, and has highlighted the risks and challenges that lie ahead for many Indian cities, including Bangalore. These crises, combined with the global examples of countries managing water effectively in a long-term sustainable manner, such as that of Israel, have ensured that the momentum around effective water management has been increasing and that the sector is being accorded a high priority in the national policy agenda.





CHAPTER V

WATER SECURITY: AWARENESS AND RESPONSIBILITIES:

Water security implies affordable access to clean water for agricultural, industrial and household usage and is thus an important part of human security. Water along with food and energy forms a critical part of the 'new security agenda' and redefines the understanding of security as a basis for policy-response and long-term planning. Water security for India implies effective responses to changing water conditions in terms of quality, quantity and uneven distribution. Unheeded it can affect relationships at the inter-state level and equally contribute to tensions at the intra-provincial level. The Union Ministry of Water Resources has estimated the countries water requirements to be around 1093 BCM for the year 2025 and 1447 BCM for the year 2050. With projected population growth of 1.4 billion by 2050, the total available water resources would barely match the total water requirement of the country. In 1951, the annual per capita availability of water was 5177 m3, which reduced to 1342 m^3 by 2000.

The facts indicate that India is expected to become 'water stressed' by 2025 and 'water scarce' by 2050. The National Commission for Integrated water Resource Development (NCIWRD) has estimated that against a total annual availability of 1953 BCM (inclusive of 432 BCM of ground water and 1521 BCM of surface water) only 1123 BCM (433 BCM ground water and 690 BCM surface water) can be put to use, i.e., only 55.6 percent. The high-level of pollution further restricts the utilisable water thus posing a serious threat to its availability and use. The subcontinent has large river systems. Prominent are the Indus basin in the west and the Ganga-Brahamaputra-Meghna basin in the east. A number of bilateral treaties exist but are often hostage to the prevailing political animosity. Resource nationalism will increasingly dominate the hydrological contours of South Asia and will largely define regional politics. The treatment of rivers as a good in the subcontinent will primarily be interpreted within the regional asymmetry/symmetry power configuration. The upstream-downstream supply disputes will commonly feature in the riparian politics. The hydrological contours of India, both as an upper riparian and a lower riparian, is at the epicentre of new riparian politics and diplomacy over transboundary rivers. The friction in bilateral relations will increase if mutually acceptable bilateral or multilateral framework for cooperation to deal with integrated development of water resources is not effectively reworked. In such situations, many of the existing treaties will have to be evaluated afresh and many treaties need to be framed based on new hydrological knowledge. India's riparian relation with its neighbors is becoming progressively fragile with Pakistan, Bangladesh and Nepal continuously raising concerns over regulating and sharing of river waters. River is an important tool for regional cooperation.

China's aggressive south-to-north water diversion projects on the rivers that originate from the Tibet region, particularly on the Yarlung-Tsangpo, is opening up a new front of uncertainty in Sino-Indian relations as well as the overall hydrological dynamics in South Asia. China's proposed dams on the Yarlung-Tsangpo are a matter of concern. The proposed dams on the Yarlung, almost 28 in number, some of which are already underway, has the full support of the state-run hydro-power industry. It would have a capacity of 38 giga watt of power, almost twice the capacity of the Three Gorges Dam.

It is important for India to create global awareness about the water resources in Tibet and build regional pressure. Tibet's water is for humanity, not for China alone. Almost 2 billion people in South and Southeast Asia dependent on the water resources of Tibet. Tibetans need to be also sensitised to the water resources and the extensive ecological damage that China's water diversion plans can cause.

International laws on allocating water within river-basin are difficult to implement and often contradictory. The UN Convention on the Non-Navigational Uses of International Watercourses approved in 1997 by a vote of 104-3 (but not yet ratified) requires watercourse nations (Article 5) to participate in the use, development, and protection of an international watercourse in an equitable and reasonable manner. In spite of the UN Convention, riparian nations pitch their respective claims and counterclaims based on their interest and interpretation. This raises fundamental questions on whether formal arrangements on long lasting peaceful sharing of river waters can be achieved particularly in regions where the political climate is hostile to cooperative endeavours.

With Pakistan and China water issues is far more political and strategic. Water as an instrument and tool of bargain and trade-off will assume predominance because the political stakes are high. Water issues between Pakistan and China have the potential to become catalysts for conflict. Though the importance of politics cannot be discounted in India's water relations with Nepal and Bangladesh, there is however far more scope to overcome and break political deadlocks through sensible water sharing arrangements and resource development. With Bhutan hydro-relations has been extremely beneficial. Sharing the benefits of river cooperation has given substance to the relationship. The growing confidence has led to a recent agreement between the two countries to develop 10 more hydropower projects with a total capacity of 11,576 MW by 2020 in Bhutan. With Pakistan, given some stringent provisions in the Indus Water Treaty that thwart India's plans of developing projects on the western rivers, a 'modification' of the provisions of the treaty should be called for. Whether it is done through renegotiations or through establishing an Indus II Treaty, modifications of the provisions are crucial in case of the western rivers.

Under the draft provisions of the International Law Commission 'Responsibility of States for Internationally Wrongful Acts, 2001, India can consider the abrogation of the treaty so long as it is proportionate to infringement by the other side. It is well established that Pakistan aids and abets terrorist actions from its soil. India should quantify the damage it has sustained over the decades because of Pakistani support to terrorism and seek as a first step suitable compensation. The recent action taken by India in February 2019, post Pulwama terrorist attack to stop sharing the water from the eastern rivers (India has full right in control of this water) with Pakistan has send the correct message. In the future India may retain the option of managing water from western rivers as a coercive action to put pressure on Pakistan when the situation demands.

With Nepal, India needs to bring about a turnaround in the overall dysfunctional relationship and invest in long-term political linkages. Considering the sensitivity of water relationship and the benefits that can come about, India should invest in Nepal's water infrastructure particularly irrigation and flood control. Identification and feasibility studies on small and medium projects should be undertaken. Small run-of-river projects should be started to build in political confidence. Nepal may be used for water storage.

With Bangladesh, India's approach should be to deal with water issues in the overall political and security context. While the Ganges Treaty is well established, concerns over the sharing of the Teesta and India's construction of the Tipaimukh dam is opening up new fronts in water relations between the two countries. While it is important to continue dialogue with Bangladesh on joint river basins, India needs to look after its own interest as well. Bangladesh also needs to be sensitized on China's long distance transfer of waters of the Brahmaputra. Brahmaputra water management is all about India and Bangladesh. There’s larger flow of water on Indian side of Brahmaputra. We have until now failed to manage (restore and storage) this important water asset. If managed well India will benefit from 1800 km of Inland water way[30]. Also we may consider de-linking China and make Brahmaputra water management a bilateral issue.

Freshwater scarcity poses a very serious, complex and potentially wide-ranging threat to regional stability. This threat could manifest itself in a number of different ways; such as directly in the form of violent conflicts over freshwater resources, or indirectly, by causing large-scale migration and food shortages. To fully appreciate the complexity of the water security issue, it has to be viewed on three basic levels.

Human Security

Freshwater can become a security issue when it is linked to so-called ‘human security’, which encompasses a variety of issues that have an impact on human health

[30] UK Sinha, NMML

and well-being. From this perspective, water is a clear security problem if one considers the large number of human deaths that occur as a result of unsafe or inadequate water. Approximately 25,000 people die every day from water related diseases. In Bangladesh, it is estimated that three-quarters of all diseases are linked to unsafe water and inadequate sanitation facilities. About 60 percent of all infant mortality throughout the world is tied to infectious and parasitic diseases, most of them related to water. Diarrhoeal diseases, moreover, are prevalent in countries with inadequate sewage treatment. An estimated 4 billion people per year contract diarrhoeal disease and among that number approximately 3-4 million die annually, and most of these people are young children.[31] Unsanitary water is clearly a major health threat for millions in the developing world. Rivers are one of the major sources of fresh water. Economic prosperity of any country depends upon its natural resources and river water is one of the most important natural resource.

Regarding the inclusion of freshwater as a security issue under the banner of 'human security', conflict could be divided between acute conflict and structural conflict, since 'conflict is fundamentally an incompatibility of interests'. Acute conflict - violence whether among individuals or among states - obviously results in human casualties; on the other hand, structural conflict also results in human carnage and can in fact, be much larger in scale. The problem of access to water is a structural conflict problem that results in thousands of deaths every day. If security is defined, at least partly, by number of deaths, then clearly water is a security issue.[32]

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[31] B K Pattanaik, Safe Drinking Water for all, Kurukshetra, P53, October 2005
[32] Ibid.

Internal Security and Governance

The specific impact of freshwater on intra-state security is far more complex and less easily ascertained. Although the potential for conflicts among countries over shared water resources receives much attention in the popular media, its impacts within nation-states are far more insidious and indirect. Water insecurity constrains economic development and contributes to a host of corrosive social behaviours that can, in turn, produce violence within societies. Freshwater scarcity, often causally related with other factors, such as poverty, population growth, infrastructure problems, environmental degradation, can escalate the aforementioned 'human security' problem into a national security issue. Water security can be the catalyst for large-scale migration and ethnic conflicts, which ultimately, in more dire situations, can result in a decline in effective governance, potentially leading to a 'failed state'.

International Security

Disputes among nations solely over freshwater resources are not likely to spark violent conflict. Nevertheless, there was an understanding that water security issues can have a destabilizing effect on regional and international security. Spawned by globalization, the increasing economic and political interdependence of nations ultimately means greater potential for spill over of problems. Ethnic unrest, mass migration, and declining economic conditions, fanned by freshwater scarcity, are not likely to be confined neatly within a country's borders. Additionally, the same factors that undermine the domestic effectiveness of a government systematically erode its ability to interact on an international level. This can have an adverse affect on negotiation and implementation of a wide variety of international agreements that range from collective security to economic and global environmental issues.

Water is increasingly viewed as a strategic resource, one that is to be protected and valued. Consequently, when one or more countries share water resources, the potential for disputes or conflicts is always present. Although no nation has yet gone to war over water, this potential scenario could unfold given the right conditions. A set of factors including demographics, rising demand resulting from improved living standards, the predominance of upstream over downstream the first served control the flow of rivers may stoke smouldering conflicts. The present and future projections are depicted:

Table 5.1
Present extent of water utilization by various sectors along with future projection

Sector	Present Utilisation (BCM)	Projected Demand (BCM)					
		Standing Sub-Committee of MoWR			NCIWRD		
		2010	2025	2050	2010	2025	2050
Irrigation	501	688	910	1072	557	611	807
Domestic	30	56	73	102	43	62	111
Industrial	20	12	23	63	37	67	81
Energy	20	5	15	130	19	33	70
Others	34	52	72	180	54	70	111
Total	**605**	**813**	**1093**	**1447**	**710**	**843**	**1180**

(Source: GoI, Eleventh Five Year Plan, Chapter 2- Water Management and Irrigation)

Source: Study of Assessment of Water Foot Prints of India's Long Term Energy Scenarios, (TERI), 2017

The following factors are considered as being critical determinants of water security in the region.

Agriculture

One major issue is the impact of growing food demand on global water supplies. Food production is likely be seriously constrained by freshwater shortages in the future. This is because agriculture is extremely dependent on an adequate freshwater supply. The Green Revolution resulted in increased crop yields, but achieved these yields largely through extensive irrigation and with increased reliance on freshwater. In fact, almost 70 percent of the world's freshwater supply is devoted to agriculture, and thus is unavailable for other uses. In India, this reliance is even more significant because an estimated 35 to 40 percent of the region's cultivated land is irrigated and this area produces over 60 percent of India's total agricultural output.

Thus, in India it is clear that the growing demand for food is a significant factor determining the supply of available freshwater. In India, for instance, it is commonly accepted that, with growing population demands, food production will need to be increased dramatically. Because irrigation is expensive, partly attributable to its inefficiency, it is very difficult to maintain adequate water supplies in the future. About half of the water that is used for irrigation is lost to seepage and evaporation. India, Pakistan and Sri Lanka have in excess of 30 percent of their total cropland under irrigation. Irrigation can be a powerful tool for expanding crop yields, but it can also be extremely dangerous when mismanaged. For example, mismanaging water resources can result in the erosion, water logging, and salinisation of the soil, which in turn makes the soil less able to produce crops. Poorly managed irrigation can also result in water pollution and water-borne diseases.

Industrialisation

Aside from agriculture, another factor that influences the state of water security in a particular country is its degree of industrialization. Industries account for roughly 25 percent of the world's water use and that number is much higher in industrial countries (as high as 50 to 80 percent). In developing countries, the percentage tends to hover around 10 to 30 percent. Industrial activity requires massive amounts of freshwater for such activities as boiling, cleaning, air conditioning, cooling, processing, transportation, and energy production. As developing countries industrialize, they will use greater quantities of water. The positive side of this trend is that water used in industrial processes can be recycled, since, unlike in agriculture, very little of it is actually consumed. In developed industrial countries, the primary impetus for water recycling is in compliance with pollution laws. Since it is often more economical to comply with pollution laws by recycling water, less is wasted. Unfortunately such trends are not as apparent in poorer developing countries where few governments provide industry with incentives to adopt more efficient water-use practices. Consequently, although the amount of water being used for industrial purposes is decreasing in the developed world, it is actually increasing in poorer, developing countries. This further strains freshwater resources in countries already facing rapid urbanization.

Environmental Factors

Environmental factors (such as pollution or climatic change) are also influencing water security. In many parts of South Asia, pollution is a major culprit behind dwindling supply of fresh water. In developing countries, roughly 90 to 95 percent of all domestic sewage and 75 percent of industrial waste are discharged into surface waters without any treatment. All of India's 14 major rivers are polluted, primarily they transport 50 million cubic metres of untreated sewage into India's coastal waters every year. New Delhi is alone responsible for dumping more than 200 million litres of raw sewage and 20 million litres of industrial waste into the Yamuna River as it passes through the city.

Another potential environmental threat to water security is global warming and climate change. Changing weather patterns could result in droughts in areas accustomed to plentiful rain and vice versa. In 1997, for instance, unusual weather patterns resulting from *El Nino* weather phenomenon left many South Asian countries with little rainfall.

Land degradation is also another environmental variable that can influence the availability of water. As countries experience greater urbanization or deforestation, less land is available to absorb and hold water, consequently, rainfall likely results in flash runoff. This leads to reduced seepage and aquifer recharge. Deforestation is rife in the region. In India, land degradation has resulted in reduced aquifer recharge, even in areas that receives large amount of annual rainfall. As a result, many village authorities in high rainfall regions petition the Central Government for drought relief.

Demographic Factors

At the beginning of the 20th century, the world's population was roughly 1.6 billion, but by 1990 it had increased to 5.3 billion, an increase of 330 percent. Currently, the world's population is increasing by around 80 million per year and is expected to reach 8 billion by 2020. Roughly half of this population will live in Asia, although Asian countries occupy about 16 percent of the world's total land surface. [33]

[33] A Chelladurai, New Approaches to Prevent Water Scarcity Kurukshetra Quaterly, p5.

The largest and most combustible imbalance between population and available water supplies is in Asia, where crop production depends heavily on irrigation. Asia today has roughly 60 percent of the world's people but only 36 percent of the world's renewable fresh water. China, India, Iran, and Pakistan are among the countries where a significant share of the irrigated land is now jeopardized by groundwater depletion, scarce river water, a fertility sapping build up of salts in the soil, or some combination of these factors. Groundwater depletion alone places 10 to 20 percent of grain production in India at risk. Water tables are falling steadily in Punjab, which is a major bread basket for India.[34]

Thus population growth in India is seen as a major challenge for water security in the region. Related to population growth is the growing trend of urbanization, which is expected to shift water out of agriculture to supply drinking water for growing cities.

Conservation Factors

If water is used more efficiently, in agricultural, industrial and municipal settings, it could help ensure water security. In many irrigation systems, as little as 37 percent of the water used is actually absorbed by crops; the remainder is lost through evaporation, seepage or runoff. According to Food and Agriculture Organisation of the United Nations (FAO), more than 10 to 20 percent of the water used for agricultural purposes could be saved if more efficient irrigation methods were utilized.[35] In Pakistan, for instance, if the efficiency of the irrigation system be increased by 10 percent, the water saved could irrigate another 2 million hectares. Water in urban areas is also wasted. In developed countries, about 10 percent of water

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[34] Ibid

[35] Sarvotham H, (2004), Water: Resource augmentation, Management & Policies p117. Delhi

is lost due to leaks in municipal water networks; in developing countries, this number could be as high as 60 percent.

Our vision for a strong India in the year 2020 has to begin with building up a mammoth stock of agricultural products far in excess of our own requirements. We cannot afford to remain complacent on our successful encounter with 1997-98 economic slide-down, that the other countries in our neighbourhood had suffered. Our efforts to raise bumper crops year after year hinge on our ability to fight drought like conditions. This would be possible only by making provision of ample water for agriculture. Towards this the National Water Policy was adopted by the National Water resources council in its fifth meeting held on 1 April 2002 at New Delhi. To achieve the desired objectives of the policy, each state has to formulate its own State Water policy, backed with an operational plan.

Policy and Governance

It is critical to have effective policymaking and governance in the management of a common, finite resource like water. Water's position on the State List in the Constitution means that state governments are the ultimate custodians of the resource, with the centre limited to an advisory and coordinating role. This theme, then, is critical for identifying achievements and practices around state policies, which form the basis for outcomes across many of the indicators described above. The theme includes four main indicators covering a broad range of water management practices, including legislation for the protection and restoration of water bodies, a framework for water harvesting in buildings, the pricing of urban water, and the existence and regular validation of integrated data for water in the state.

Use of technology for water mapping in the country for complementing the efforts towards ensuring water security. Towards this the use of GIS and its application for solving environmental problems is growing rapidly. This powerful set of tools can be used to great effect in hydrological modeling, environment and habitat assessments, ecosystem studies, monitoring of wetlands and forested watersheds, urban studies, agricultural impact assessment and much more. GIS for Watershed and Water Resource Management explains the fundamentals, demonstrates new approaches, techniques and methods, and provides examples of real applications. It presents the basic concepts, and shows how to acquire the critical information needed to plan and implement GIS studies, and develop practical solutions for environmental management and problem solving. State-of-the-art GIS spatial data management and analysis tools are revolutionizing the field of water resource engineering. Familiarity with these technologies is now a prerequisite for success in engineers' and planners' efforts to create a reliable infrastructure. GIS in Water Resource Engineering presents a review of the concepts and applications of GIS in the various sub-fields of water resource engineering in the following areas:

- Surface Water Hydrology
- Groundwater Hydrology
- Water Supply and Irrigation systems
- Wastewater and Storm water Systems
- Floodplain Management
- Water Quality
- Water Resource Monitoring and Forecasting
- River Basin Planning and Management

The satellite can provide information on hydrologic land use, run off, recharge, and storage and discharge areas. Features of inaccessible areas like reservoir water contours and crop water use zones are successfully captured and monitored by using satellite remote sensing capabilities. The main hydrological application field of remote sensing are the following:-

- Spatial rainfall patterns, evaporation and soil moisture, snow cover extent, ground water, topography, water bodies and vegetation.

GIS has made hydrological modelling more effective. Without spatial bias, it was difficult to handle data of geographical parameters. India has the largest constellation of remote sensing satellites. Remote sensing utilizes the interaction between electromagnetic radiations for water. Water vapour, ice snow and water bodies appear in the satellite imaginary as dark regions. High resolution Imagery form IRS series are very important regarding mapping of ground water.

Water Security and Sustainability in Urban India

The rapid growth of population combined with rising levels of consumption and pollution has increased water insecurity in urban India. The depleting water sources on the one hand, higher financial and technological costs to refine and transport water from far off sources on the other, leave limited possibilities to augment the water supply in the near future. Climate change may further adversely impact the available sources of fresh water supply. Intra-urban and inter-class water supplies are also issues in Indian towns and cities. A large section of population in urban India collects water from public and private sources located far away from their residence and bears direct and indirect enormous opportunity cost.

Causes and Dimensions of Water Insecurity in Urban India

The water security can be defined as the ability of different section of population to access sufficient quantities of clean water to maintain adequate standards of food, sanitation, health and production of goods (Institute for the Analysis of Global Security, 2004). In other words, water security means that every person has access to enough safe water at an affordable cost to lead a healthy and productive life and that the vulnerable are protected from the risks of water related hazards (Ministerial Declaration of The Hague, 2000). The affordable price dimension of water security in urban context also involves supply of water at premises, as the time, health and other social costs of collecting water from outside the premises are substantially higher.

The water availability for public purpose, like fire tenders, greening, parks, sport complexes, and sustenance of cultural-ecologies in urban areas are also essential. Several factors like rapid growth of population in urban centers, particularly in big cities, limited sources to augment water supply, increased demand and pollution, limited recycle and reuse, discussed below, have led to a rising water insecurity in urban centers in the country. The climate change possibility and its likely adverse impact on water availability further portray a bleak picture of sustaining water supply to urban centers in future.

Rural Population in India

About 70 percent of India's population, approximately 800 million people, lives in rural areas, making this one of the largest service delivery challenges in the world in terms of scale. While access has improved markedly in recent years, with almost 87 percent of rural households having access to 'basic water'[36], the provision of safe water remains a large challenge. Currently, only half of the rural population has access to safely-managed water[37] far behind even our neighbors such as China

[36] WASH watch.org
[37] WHO/ UNICEF Joint Monitoring Programme (JMP)—washdata.org

and Bangladesh resulting in one of the highest disease burdens due to water-borne diseases in the developing world, and about two lakh annual deaths from inadequate (or unsafe) drinking water.

Interstate Water Dispute.

Efforts should be made to settle all interstate water disputes by negotiated agreements among parties, by mutual understanding undivided by political/administrative frontiers. The rights of different states may be determined by applying the rules of equitable apportionment, each unit getting a fair share of the water of the common river, in the general interest of the community. The geographical factors should be given preference not the political division. Water has to be considered as government property and it has to be protected from all sorts of pollution by enacting stringent laws. The state and central government must act in unison to resolve all disputes.

Inter- Linking of Rivers

'Arthur Cotton' was the first person who originally conceived the idea of networking the rivers about two centuries ago. It was the Supreme Court of India which ordered the Government on 31 Oct 2002 to complete this project in the next 12-15 years. In response the Government appointed a task force of scientists, engineers, economist, biologist and policy makers to ponder over the technical, economical and eco- friendly feasibility of this gigantic project. The completion of this project will result in constant water supply for domestic use, agriculture and industries along with flood control. It would also bring in an extra 34 Mha of land under irrigation using 173 BCM of additional water created by this project along with production of 34 giga watts of eco- friendly electricity. The project is expected to be an engineering marvel.

Water linking is a herculean task. It will require enormous capital. Scientific approach to be adopted for providing long term water resource management. It has to make use of all scientific and technological developments for investigation, planning, design, implementation and operation of various schemes. Towards this water flow management is an important aspect. Augmentations of rivers require improvement and our storage capacity especially in the NE region may be explored for ensuring water security. The initiatives taken by the current government towards Interlinking of rivers and the status update are placed at 'Appendix B'.

Water Harvesting

WH is now being popularised as a measure to augment or replenish ground water supplies particularly in areas facing the problem of lowering the level of water table. The process is nothing new. Only the ancient wisdom has been put to practice in the present circumstances due to the problem of water scarcity particularly the ground water. Because of the technological innovations available today modern methods are available to optimally utilise this methodology. The two chief methods being followed are Root Top Water Harvesting and Check Dams.

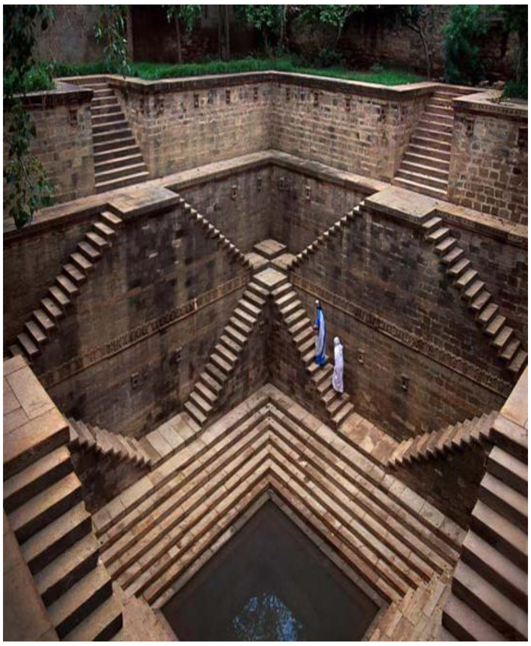
Integrated Water Resources Management (IWRM)

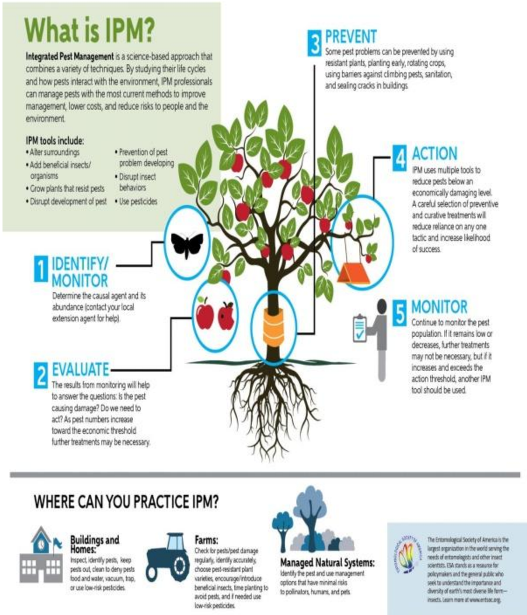
It also enables the operationalization of IWRM as a system approach to secure water resources through strengthening of the interactions of various systems, subsystems, and the elements within the entire basin system. To this end, strengthening water resources information systems, recognizing and balancing water as economic and public goods, creating awareness among key stakeholders, encouraging the engagement of private sectors in water resources development and management should be considered as mediums of realizing IWRM.

Climate Change

Climate change resulting in global warming is a major challenge affecting the water availability scenarios in the country. This factor is projected to have direct impacts on livelihoods and raising concerns for food security, water supply, health and energy. Changes in temperature pattern due to global warming have consequential impacts on precipitation patterns, both globally as well as regionally. As precipitation is the key regulator of surface water availability in any area, it gets severely affected due climate change. According to Intergovernmental Panel on Climate Change (IPCC) report in 2014, climate has shown warming of 0.89 (0.69 to 1.08) °C over the period 1901–2012 which is mainly attributed to anthropogenic activities.

While climate change is supposed to have an impact on water demand also, through its influence on production of crops, evapotranspiration from crops, human water demand, increasing pollution levels in water resources etc., no reliable records are available to understand alterations in water demand patterns under future climate change scenarios. The Himalayan region is the most vulnerable to climate change.





What is IPM?
Integrated Pest Management is a science-based approach that combines a variety of techniques. By studying their life cycles and how pests interact with the environment, IPM professionals can manage pests with the most current methods to improve management, lower costs, and reduce risks to people and the environment.
IPM tools include:
• Alter surroundings
• Add beneficial insects/ organisms
• Grow plants that resist pests
• Disrupt development of pest
• Prevention of pest problem developing
• Disrupt insect behaviors
• Use pesticides
1 IDENTIFY/ MONITOR
Determine the causal agent and its abundance (contact your local extension agent for help).
2 EVALUATE
The results from monitoring will help to answer the questions: Is the pest causing damage? Do we need to act? As pest numbers increase toward the economic threshold further treatments may be necessary.
3 PREVENT
Some pest problems can be prevented by using resistant plants, planting early, rotating crops, using barriers against climbing pests, sanitation, and sealing cracks in buildings.
4 ACTION
IPM uses multiple tools to reduce pests below an economically damaging level. A careful selection of preventive and curative treatments will reduce reliance on any one tactic and increase likelihood of success.
5 MONITOR
Continue to monitor the pest population. If it remains low or decreases, further treatments may not be necessary, but if it increases and exceeds the action threshold, another IPM tool should be used.
WHERE CAN YOU PRACTICE IPM?
Buildings and Homes:
Inspect, identify pests, keep pests out, clean to deny pests food and water, vacuum, trap, or use low-risk pesticides.
Farms:
Check for pests/pest damage regularly, identify accurately, choose pest-resistant plant varieties, encourage/introduce beneficial insects, time planting to avoid pests, and if needed use low-risk pesticides.
Managed Natural Systems:
Identify the pest and use management options that have minimal risks to pollinators, humans, and pets.
The Entomological Society of America is the largest organization in the world serving the needs of entomologists and other insect scientists. ESA stands as a resource for policymakers and the general public who seek to understand the importance and diversity of earth's most diverse life form—insects. Learn more at www.entsoc.org.

PURIFICATION AND TREATMENT
Drinking water treatment using near-nature methods, emergency units, recycling of gray water.
CONTAMINATED LAND REMEDIATION
Nanoremediation, steam enhanced extraction, reactive barriers, in-situ remediation, design services, monitoring.
WATER RESOURCES
Complete services for water resources, including new resources, pumping tests, well diagnostics, regeneration, remediation and decommissioning of wells.
WATER MANAGEMENT
Studies and projects, storm water, self-operating sites, small water reservoirs and watercourses, flood protection and prevention, algae control.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

Water crisis in India is mainly an issue of governance, and not merely one of scarcity. Procrastination in settling water disputes does not pay. The challenge for the country would entail de-politicising water conflicts, taking advantage of strengths of democratic institutions, while containing their weaknesses. There are three possible routes, which are not mutually exclusive but distinct, to achieve institutionalized cooperation:-

- **Strengthening Existing Institutions and Conflict Resolution Mechanisms**: Several mechanisms and principles have been adopted in India for dispute settlement. Some have yielded excellent results, while others have ended in long drawn legal battles in courts. The existing institutions consist mainly of special tribunals, courts and water development bodies. Alternate dispute resolution mechanisms such as mutual discussions and negotiations also exist. In some cases the process of negotiations was successful in conflict resolution. However, in recent years, this approach has not met much success. There is a requirement to strengthen such mechanisms.
- **Establishing Integrated River Basin Management Organisations**: River Basin Organisations should be set up for ensuring integrated development of river basins. This envisages a legal and regulatory framework to ensure optimal utilization of water with appropriate sectoral allocations.

- **Establishing Economic Cooperation Forums for Water Negotiations and Management**: Valuation of water resources enables a simpler, more open assessment of international exchanges than is possible with the existing forms of diplomatic barter. Like other resources (oil, gas, minerals etc) water can be profitably traded between water surplus and water short countries.

Access to clean, safe, freshwater is recognized universally as one of the most basic and vital needs of humanity. Water shortages in the next few decades can potentially have broad and far reaching security implications. At its most fundamental level, water security is a human security problem. In the short term, the possibility of nations engaging in direct conflict over water resources is unlikely. However, water insecurity can indirectly affect events that have a direct bearing on regional security.

Due to its location, size and contiguous borders with Pakistan, Nepal and Bangladesh, it is India, in its capacity as both upper and lower riparian, that has come into conflict with most of its neighbours, except Bhutan, on the cross-border water issues. Given an atmosphere of mistrust, India has serious issues to resolve with lower riparian Pakistan and Bangladesh, and, upper riparian Nepal. While India may not be responsible for certain deadlocks, its share of responsibility may be larger than other countries which have their own physical limitations and political apprehensions.

The onus, therefore, lies on India to engage and convince its neighbours that together they must take a holistic view of the Himalayan river-grid. Mutual understanding and cooperation amongst these riparian states should make it a weapon not against each other but against their poverty, underdevelopment and disease. Apart from such cooperation improving the atmospherics, this will save their people from the annual fury of drought and floods and help them in utilising these river systems for irrigation, navigation and power generation thereby bringing prosperity to the region.

As water shortage increases alternate sources of water supply are gaining importance. These include sewage recycle, rainwater harvesting etc. In fact water recycle is simple, effective and economical solution to conserve water so that more fresh water is available for uses such as drinking, bathing, cooking and laundry. Sewage recycle would reduce infrastructural costs on public water systems as well as heavy losses during the distribution. Recycling must be made mandatory for all new projects – industrial or domestic.

Industrial effluent recycle solutions integrate physicochemical, biological and membrane separation processes for optimum water recovery. They conserve water through recycle of waste water and recover valuable products for reuse, thus giving industries a good return on their investment while protecting the environment.

We need to also create awareness about importance of water in the community so that mindset, attitudes and habits change proactively rather than wait for legislation and regulations. Together we must work to see that waste of this precious resource is minimised and we are able to conserve fresh water for our future generations. Towards this the media has a major role to play. It is only through the reach of media that this can be converted to a mass movement.

Civil engineers of the country will need to be given a capsule to develop watersheds and ground water basins by construction of percolation structures like trenches and pits while executing public works. An insight into building integrated rooftop rainwater harvest cum groundwater recharge structures in the existing urban sprawls by minimal altering of the existing structure of public buildings will also encourage others to follow.

Plans and Policies

Water sector is very delicate here because of water scarcity. Yet, water planning, management, and decision-making processes are increasingly messy. Hence a comprehensive and all inclusive policy required. Water Resource Management (WRM) problems need to be understood holistically.WRM implementation should be through a bottom-up and decentralized approach. Some of the measures adopted by Government of India which would go a long way in complementing water security in the country are adopting various water security policy decisions and initiating and implementing various water rejuvenation schemes. They are depicted below:

Water Policy Timeline in India

- Right to water recognized: - Supreme court recognizes right to water as a part of right to life
- National river linking revitalized
- Ministry of Water Resources, River Development & Ganga Rejuvenation established.
- Model Ground Water bill framed
- National Water Policy revamped
- Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) launched
- *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) launched
- India-Israel water partnership formalized

Water governance in India adopts excessively centralised top down, linear approach. Large irrigation projects are managed by bureaucrats bosses over the community organisations. The farmer community was sidelined by the irrigation department. Onslaught of formal structures of representative democracy resulted in the breakup of the existing traditional system. Appropriate bottoms up, participatory and empowerment method of action is suggested.

For too long the Government and techno-centric policy makers have responded to water scarcity through grandiose ideas of big structures , linking alters and creating mega reservoirs, but not through community water banks, a fertile source of recharging ground water. Previous water policies have focussed practically exclusively on augmenting supply thus paying less heed to conservation and more optimum utilisation. The policy has no provision for creating awareness on multi dimensional nature of water use and also for disseminating information and education on promotion of retention of soil moisture, the cultivation of higher value but low water requiring crops like pulses oil seeds and some herbal plants.

There are numerous illustrations and ways in which water can be more effectively utilised in large part by involving users themselves. An effective strategy to mobilise the public for collective action should use the three necessary steps:

- Participation by targeted group
- Partnership with target group
- Empowerment of target group

Lacunae in legal framework and legal litreacy, following points merit consideration:-

- Redefine relationship between land and water rights. Legal limits to ground water exploitation to be in place.

- Modify irrigation legislation provisions for disputed settlement
- Explicit recognition of the gender and class character of access to water
- States accountable for failure to develop legal literacy among targeted group.

Initiation of knowledge revolution in rural India through effective and meaningful use of modern information and communication technology, integrated application of Satellite, Electronic and Print media and Wireless Telephony is a necessity. Use of the Mass communication devices simultaneously keeping the interest of the rural masses towards keeping them informed on water management is a must.

Mobilisation of Community for Mass Movements.

Fortunately successive governments have laid adequate stress on Panchayati raj system as a result the affected people have also started feeling the need to act together. This feeling needs to be prodded amongst the rural masses so that there no fear of reprisal from whosoever they were afraid of earlier. Water is a necessity and good water sustenance lies in conserving right from the word go and needs mobilisation of the community.

Privatisation of Water

Sheonath river in Chattisgarh flows through Borai in Durg district. A stretch of the river near Borai was handed over to a private firm to supply water to the region lying between the two district headquarters, Durg and Rajnandgaon. The period of contract is 22 years. Skirmishes between the villagers and the private firm has now been a regular affair. At the end of it is not the private firm which is to be blamed but the Government which went ahead with the contract without adequate ground work as well as keeping the local village people in the picture.

There are other instances Sonia Vihar Water Treatrment Plant at Delhi which is an off shoot of the privatisation of Delhis water supply and unbundling of Delhi Jal Board. New Tirupur Area Development Corporation limited (NTADCL) which have all been failures because of lack of proper guidelines for contracting. Delhi government in their annual budgetary proposal announced that it will be rolling out a three tier plan to make the city self reliant in water supply in the immediate future[38]. The proposal is ambitious for a city that has a supply shortfall of 225 million gallons per day (MGD) and faces repeated water crisis. The programme involves creating underground reservoirs to store rain water, tap additional water from Yamuna during monsoon and creating decentralised sewage treatment plants (SWT) to augment water supply as well as recharge groundwater. Water treatment plant has also been planned at other locations in Delhi.

Waste Water Treatment

Almost 80 percent of the water supplied for domestic use, comes out as wastewater. In most of the cases wastewater is let out untreated and it either sinks into the ground as a potential pollutant of ground water or is discharged into the natural drainage system causing pollution in downstream areas. So, there is an urgent need for treating wastewater using modern technology and recover as much usable water as possible. The conventional wastewater treatment processes are expensive and require complex operations and maintenance. In developing countries like India, the problems associated with wastewater reuse arise from its lack of treatment.

[38] TOI, New Delhi, 27 Feb 2019

There cannot be a one size fit all solution. Each pocket has its own unique set of challenges and hence identifying the real problem and creating customizable solutions to tackle it should be the need of the hour. Besides, wetlands may work in a few rural pockets but in Tier 1 cities where real estate is a luxury, it neither seems feasible, nor a part of the solution. Science and technology is here to help and pull us out of the mess that we have created for ourselves. The focus first should be on adaptive modern technologies that not only treats wastewater, are part of existing infrastructure.

Suggestions/ Recommendations towards Water Resource Management and Ensuring Water Security in the Future

Water crisis in India is mainly an issue of governance, and not merely one of scarcity. Procrastination in settling water disputes does not pay. The challenge for the country would entail de-politicising water conflicts, taking advantage of strengths of democratic institutions, while containing their weaknesses. Extensive utilisation of emerging technologies is recommended for optimum utilisation of the depleting water resource and efficient management for committed water security in India's future. Some of the recommendations are elaborated:

- **Water Shed Development**

  It is evident that water shed management has transitioned to a more holistic resource management employing integrated and adaptive management strategies to account for biological , physical and social elements within the landscape of technological advancements. There is improved accuracy in data collection techniques and model development and it has become possible to develop integrated multilevel analysis that generates more complete information about the watershed system both socially and ecologically. These improvements in watershed management and use of emerging technologies like Remote Sensing, Geographical Information System, Global Positioning System, Internet, Big Data and Meta analysis provide more comprehensive and multidimensional information for decision makers to assess the status of watershed and implement necessary regulations. The policy makers need to exploit our expertise in this field of modern and satellite technologies for futuristic and efficient watershed management.

- **Urban Water Pricing**

In India all urban households are charged nothing for water, leading to over usage. The full cost pricing of water services has yet to take hold in India. As a result, it remains broadly underpriced leading to public perception that water is "free". The current tariff levels are too low to cover even the operating costs. There is a requirement to charge the consumer with all inclusive cost to improve the cost recovery. There are several studies on the subject. Effective implementation process would eventually lead to long term socio-economic sustainability.

- **On Farm Water Management**

The water management and strategy for the development of irrigation has to be formulated for each region taking into account its agro potential and temporal need of water. The On farm water management improves agricultural productivity by enhancing efficient use of water. Concerted effort is required to look into all aspects of farm management which include rehabilitation of irrigation canals, institutional strengthening, support and enhancing productivity, capacity building of Ministry of Agriculture, irrigation and Livestock. The government agency to assist effective agriculture implementation and its evaluation and analysis and give correct advice to the farmers to get the best result for the money they have invested through increasing the coverage of micro-irrigation and drip irrigation and use of modern technology.

- **Ground Water Rejuvenation and Restoration**

The paradigm shift that has taken place in ground water withdrawal and management policies for sustainable water utilisation which has started replenishing the aquifers in western and southern parts of India is to be studied and implemented across the country. All the areas need to be mapped and adequate recharge infrastructure constructed state wise. Well rejuvenation also requires improvement.

- **Ground Water Regulation**

There is an urgent need to improve ground water management in agriculture sector as the millions of ground water abstraction structures being used for agricultural purposes may adversely impact the livelihoods of millions of small and marginal farmers. Government needs to deliver technological interventions that are sustainable and evolve dynamic policy response on the matter because it has far-reaching implications and consequences for every Indian regardless of the Gender, age, religion and caste.

- **Participatory Irrigation**

Many states in India have done well in participatory Irrigation management through Water User Associations (WUA). Some of the issues that require immediate attention are allocation of national fund for canal rehabilitation. A robust institutional mechanism is required in all states which clearly lays down responsibilities for funding, collection of water charges and also ensure greater transparency in the working of the irrigation department and more effective functioning of upper level organisations. A formal handing over of canals to the WUA members can be a huge step towards improving their sense of ownership and improving accountability.

- **Water Harvesting**

Conservation of water has become an important component towards ensuring water security in future and ensuring greener tomorrow. The world requires a low cost clean supply of water for years to come. The rain water harvesting techniques have been in existence since decade now. But it is the humans, who waste and pollute the water and we are responsible for the increasing scarcity of clean water. We have to come with innovative methodologies with the help of technology to harvest water. Some of the successful methods covered in the research may be adopted by all states across the country based on their requirements. It becomes duty of all citizens to come up with ways to reduce water pollution and wastage so that the entire ecology does not suffer. Rainfall is the major source of irrigation in India which is directly dependent on the amount of forest water. The deficiency of rainfall causes drought and famine. Hence, we should conserve forest as well because rainfall and forest cover has close relationship.

- **Surface Water Restoration**

The level of water above (surface) and below (ground) are interconnected. Overdrawing ground water can not only cause the ground to sink, it can also lead to a river or lake disappearing. Similarly surface water helps maintain the ground water supply when it can slow down enough to seep into the water table. The successful projects adopted by various states to restore surface water have been covered in the research. The states/districts are made responsible for creating water restoration methods to create benefits for the survival of human beings and wild life in the face of a changing climate and variable water supply. An added benefit would be creation of large benefits for the survival of endangered species. Reconnecting surface and groundwater is vital for a resilient watershed.

- **Policy and Data**

It is vital to update and improve the National Water Policy. The Water Policy should take into account the updated figures of demand and supply and incorporate modern water management methodologies and conservation technologies. It should also factor the international dimensions of water sharing. In particular, the Policy should focus on water cooperation with India's neighbours. It is recommended that river waters should move up in India's foreign policy priorities. In so far as the neighbours are concerned, conflicting interests, particularly the distributive issues of river waters getting more of what is in dispute - is clearly the more critical and immediate concern. Due attention should be given to multilateral efforts involving river-basin actors on water management issues. So enacting legislation and setting up integrated water data centre is to be completed by the decision makers.

- **Rural Drinking Water**

Access limited and quality poor several organizations in India are experimenting with decentralized technologies for measuring and improving water quality, and state governments can benefit from partnering with these organizations to pilot and scale promising technologies. Improving water quality in the rural areas of some of India's largest states remains the major challenge.

Conclusion

Water conflicts in India have now percolated to every level. They are aggravated by relative paucity of frameworks, policies and mechanisms to govern use of water resources. Effective conflict resolution calls for a consensual, multi-stakeholder effort from the grassroots upwards. In India water conflicts are likely to worsen before they begin to be resolved. Till then they pose a significant threat to the economic growth, social stability, security and health of the ecosystem and the victims are likely to be the poorest of the poor as well as the very sources of water-rivers, wetlands and aquifers.

Many countries have developed strategies for their economic growth. Those countries propose to achieve their envisioned growth mainly through the areas of agriculture and industries. Infusion of advanced technologies in all spheres of their activities is the foremost item in their agenda. India too has a similar agenda for the future and is continually striving in that direction. Much needs to be done in the areas of water resources augmentation, to which availability of power is crucial. If the plans were to fructify, by the next decade at least 70 percent of the power supply available in the national grid to various segments of activity in the country including the power supply to a large number of water treatment and seawater desalination plants should come from nuclear source. If we work towards this mission, by the next decade India would possess adequate amounts of water and electricity, which would be able to protect the needs of agriculture and industries of all kinds and also the requisite quantities of protected water sources to meet the daily demand of potable grade water by every citizen of the country.

In the current Indian context, the biggest challenges regarding water management are to meet the growing demands of various sectors such as Agriculture, Industries, urban water drinking needs, sustaining ecology and environment. There is an urgent need to prevent over use of water and its degradation due to pollution. Water treatment require concerted effort as the untreated waste water gets dumped in rivers, streams, ponds, tanks and waste lands. This contributes to water contamination-both surface and sub surface. Concrete efforts are required to resolve the issue by elected governments (Both state and central). All the challenges faced by water sector need to be included in the policy and political frame work. New institutions are required that allow a negotiated approach to water resource governance. An unified approach by all stake holders including the state, the bureaucracy, the environmentalists, the civil engineers, the NGOs, the international funding agencies are required.

The task of uninterrupted supply of pathogen free drinking water to the masses of population of the country has to be taken up in the form of a revolution or movement, just like the governments take up pulse polio programmes. Disinfection of water to the level of potable grade, with aid of domestic or government sponsored community level UV ray electronic machines would be a pragmatic way of ensuring that all people in the country including the villages get clean drinking water.

The UV ray based electronic disinfectant machines should be manufactured and sold in the country in such large numbers as comparable to those of television sets. Advertisements in mass media encouraging people to buy these machines need to be launched in an aggressive manner. The Union as well as the State governments should extend subsidy in its annual budgets to these UV ray disinfectant manufacturers for a period of 10 years so that all are in a position to buy and install one at home.

As population increases, as people's expectations for comfortable lifestyle increases, as water resources becomes scarcer, as less quantity of essential commodity like water has to be shared with more people, and as all these things happen simultaneously, we necessarily have to adopt sound techniques in managing our water resources by changing our priorities and adapting ourselves to new habits. We have to pick up the signals of alarm transmitted by climatic changes, global warming, El Nino, errant monsoons, truant rainfall, retreating glaciers and droughts in time and act fast. Lest we may ourselves gradually end up living amidst geographic conditions that are alien to those of the present times and be heading towards lost civilisations.

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Appendix 'A'

(Refers to Page 57 of chapter IV)

BASINWISE GROUND WATER POTENTIAL OF INDIA

(Cubic km/Year)

S No	Name of Basin	Total Replenishable Ground Water Resources
1	Brahmai with Baitarni	4.05
2	Brahmaputra	26.55
3	Cambai Composite	7.19
4	Cauvery	12.30
5	Ganga	170.99
6	Godavari	40.65
7	Indus	26.49
8	Krishna	26.41
9	Kutch and Saurashtra Composite	11.23
10	Madras and South Tamil Nadu	18.22
11	Mahanadi	16.46
12	Meghna	8.52
13	Narmada	10.83
14	Northeast Composite	18.84
15	Pennar	4.93
16	Subarnrekha	1.82
17	Tapi	8.27
18	Western Ghat	17.69
	TOTAL	**431.42**

Appendix 'B'

(Refers to Page 105 of chapter V)

INTERLINKING OF RIVERS: STATUS UPDATE

Achievements of Interlinking of Rivers (ILR) Programme

- Interlinking of River (ILR) programme is of national importance and has been taken up on high Priority. Hon'ble Minister for Water Resources, RD & GR is monitoring the progress of ILR from time to time. The mission of this programme is to ensure greater equity in the distribution of water by enhancing the availability of water in drought prone and rain-fed area.

- Under the National Perspective Plan (NPP) prepared by Ministry of Water Resources, NWDA has already identified 14 links under Himalayan Rivers Component and 16 links under Peninsular Rivers Component for inter basin transfer of water based on field surveys and investigation and detailed studies.

- Out of these, Feasibility Reports of 14 links under Peninsular Component and 2 links (Indian portion) under Himalayan Component have been prepared. Draft Feasibility Reports of 7 link projects (Indian portion) of Himalayan Component have also been completed.

Special Committee for ILR

As per the decision of the Hon'ble Supreme Court, a Cabinet Note on ILR was submitted to Union Cabinet on July 16, 2014.

- Union Cabinet in its meeting held on July 24, 2014 approved the constitution of the Special Committee on ILR.

- Accordingly, Special Committee on ILR as per the directions of the Hon'ble Supreme court was constituted vide order dated September 23, 2014.

- Fifteen meetings of the Special Committee for Interlinking of Rivers (ILR) have been held so far on October 17, 2014, January 6, 2015, March 19, 2015, May 14, 2015, July 13, 2015. September 15, 2015, November 18, 2015, February 08, 2016, April 29,2016, July 26,2016, November 9,2016, March 8, 2017, July 27,2017, January 17, 2018 and August 20,2018 at New Delhi. The Committee, after considering the views of all the Stakeholders, is proceeding ahead to expedite the objectives of the interlinking of rivers as per terms of reference. Vigorous efforts have been taken up for generating consensus with development of alternative plans and also setting out road maps for implementation of mature projects.

- The Committee submitted its Status-Cum-Progress report to the Cabinet and the same was discussed during the Cabinet meetings held on 18.11.2015, 15.11.2016 and 06.06.2018.

- Special Committee for Interlinking of Rivers (ILR) decided to constitute four specific Sub-Committees viz.,

- Sub-committee for comprehensive evaluation of various studies / reports.

- Sub-Committee for system studies for identification of most appropriate alternate plan.

- Sub-Committee for restructuring of National Water Development Agency.

- The sub-committee for Restructuring of NWDA has held various meetings and submitted its report on 21.09.2015.

- Sub-committee for consensus building through negotiations and arriving at agreement between concerned States and

- Meetings of rest these Sub-Committees are being held regularly and their assigned works are in progress.

Regional Conferences

- As decided in the 14th meeting of Special Committee for ILR held on 17.01.2018, three regional conferences have been organized on water resources of States viz., 20.02.2018 at Hyderabad for Southern region, 16.04.2018 at Kolkata for Eastern region and 18.06.2018 at Mumbai for Western region. During the conferences, various water related issues were deliberated/discussed.

Task Force for ILR

- A Task Force for Interlinking of Rivers has been constituted by the Ministry on April 13, 2015 which also meets the requirement of Committee of experts as directed by the Cabinet while approving the constitution of Special Committee. Ten meetings of Task Force were held on April 23, 2015, November 05, 2015, April 28,2016, June 15, 2016, October 25,2016, February 13, 2017, May 11,2017, September 15, 2017, May 30, 2018 and October 5, 2018.

Group on Intra-state River Links

- A Group on Intra-State River links has been constituted by MoWR, RD & GR on 12.03.2015. The Group has reviewed all relevant issues on Intra – State River Links including the definition of such link, consider and suggest about the funding of intra-state river link projects. The Group has submitted its report on 28.05.2015 to the Ministry of Water Resource, RD & GR.

Constitution of Group on Legal aspects under Task Force.

- In pursuance of the decision of the Task Force for Interlinking of Rivers taken in its 4th meeting held on 15th June 2016, a Group has been constituted by MoWR,RD&GR on 18.07.2016 to look into legal aspects and required enabling provisions for implementation of Interlinking of Rivers and other related issues. The legal group has submitted its report to Chairman, TF-ILR during March, 2017. The Chairman, TF-ILR has submitted the report to Hon'ble Minister (WR,RD&GR) on 02.11.2018.

Constitution of Group on Financial aspects under Task Force

- MoWR,RD&GR has constituted a Group on Financial Aspects on 12.09.2017 under Task Force for Interlinking of Rivers to consider the financial aspects of ILR projects and to suggest the funding pattern for implementing the same. The Group has submitted its interim report to the Chairman, TF-ILR on 7.8.2018. The Chairman, TF-ILR has submitted the interim report to Hon'ble Minister (WR, RD&GR) on 02.11.2018.